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THE UNIVERSITY OF ALBERTA

THE CONTRIBUTION OF AUDITORY FEEDBACK TO MOTOR CONTROL IN SPEECH: INHIBITION BY AUTOGENIC MASKING

BY

© W. WENDY RUSSELL

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "The Contribution of Auditory Feedback to Motor Control in Speech: Inhibition by Autogenic Masking" submitted by W. Wendy Russell in partial fulfilment of the requirements for the degree of Master of Science.

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Supervisor

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Date ..... May 31st 1973 .....

DEDICATION

To the memory of my Mother,

Winifred Spencer.

ABSTRACT

The effects of auditory feedback loss on the speech production of eight female subjects was investigated under two types of masking agent. White noise and a noise source derived from each individual subject's speech were applied binaurally at 85 dB above threshold for the individual subject. In addition, each masking agent was applied to the larynx by an external electromechanical vibrator simultaneously with binaural masking. Speech production was elicited by having subjects read aloud a standard passage of prose, respond orally to written questions and to visual stimuli. Spectrographic records were made of speech under the reading aloud condition; these data were supplemented by oscilloscopic records, qualitative evaluation of the subjects' speech, and introspective reports obtained from the subjects.

The autogenic noise was found to be superior to white noise with regard to subject comfort, the apparent degree of auditory feedback masking achieved, and the degree of speech disturbance observed.

In addition to replicating effects reported by other investigators, spectrographic data showed added shaped frequency components in the 2.5 k Hz. to 5.5 K Hz. range. These were interpreted as indicating laryngo-pharyngeal muscle tension leading to changed voice quality under the masking conditions.

It is hypothesized that the segmental articulations

are not critically dependent on auditory feedback and possibly involve either an unregulated feedback or else a closed loop, with a relatively low functional load, operating at a relatively high brain level. Voice quality characteristics due to laryngeal function appear to involve a closed loop fed by auditory feedback and proprioception.

A second hypothesis is advanced, which distinguishes between exogenic and endogenic auditory feedback, in an attempt to explain the slow onset of speech changes after sudden anacusis as compared with the immediate onset of speech change in these experiments.

Implications for further research are discussed.

ACKNOWLEDGEMENTS

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CHAPTER ONE

I. INTRODUCTION

This study is concerned with the contribution made by auditory feedback (AF) to the mechanisms of motor control in speech. The nature of this contribution might be made more clear if we could arrange to inhibit the auditory feedback, thus permitting us to observe the ensuing effect on speech output. The question then arises whether such an observation would be indicative of the function of the feedback, or of the actual mechanism of control.

There are two substantive views on the control of speech production. First, that various feedback systems are crucial and supply moment-to-moment information about ongoing movements: a closed loop system. Secondly, that feedback is not functionally important, but that control depends upon an invariant central patterning allowing anticipatory commands to the speech muscles: an open loop system. Recently a third view, the possibility of a mixed open and closed loop mechanism, has been widely postulated. The experiment reported in this study attempts to assess these alternative models so far as auditory feedback is concerned. One significance of such an attempt lies in the fact that it provides a basis for investigating the role of feedback in rapidly changing motor patterns within the cranial neuromuscular system.

Very little has been reported on the results obtained after effective masking of the speaker's own voice from

himself. There is, in fact, no agreed criterion for effective auditory inhibition by noise, although it is the only available method of inhibiting hearing in the normal subject. The ideal method would be to use subjects who had suffered traumatic bilateral sensori-neural deafness, and to test their voice characteristics in controlled experiments at onset and over a period of time. Such an experiment would be extremely difficult to arrange. Perhaps due to the inherent difficulties of contriving a laboratory situation to match a natural condition of auditory inhibition, much of the work reported on the masking of auditory feedback fails to meet the needs defined for this present study.

The main objective in this study has therefore been to improve the method of masking and to develop a technique which might further the attempt to mimic the ideal: a subject with intact, normal, language skills but totally inhibited from hearing himself speak.

Physiological and psychological experiments have demonstrated the essential importance of sensory feedback in the visual, tactile, and proprioceptive modalities in such motor activities as walking and eye-hand co-ordination. Essentially unsolved problems concern the functional mechanism of rapid and finely co-ordinated movements as opposed to reflex or relatively slow movements, and whether the control mechanisms involved in the cranial neuromuscular system parallel those of the skeletal neuromuscular system with respect to their control mechanisms.

Neurophysiological research has addressed such complex

problems for several decades. Particular progress has been reported in relation to open and closed loop mechanisms in motor control with the gradual realization of the role of muscle spindles in the gamma motor system. But although some physiologists have long regarded speech as the ultimate example of human motor co-ordination (Lashley, 1951; Eccles, 1966), relatively little work has been done in this area. This relative neglect is unfortunate since the speech control mechanisms bear directly on the two major problems mentioned above: control mechanisms in rapidly alternating motor patterns, and possible differences between control in the cranial and skeletal neuromuscular systems.

Apart from purely physiological considerations, this study bears upon the investigation of language phenomena in the context of modern linguistics. "The concern of modern linguistic theory has been to describe language in terms of grammatical systems which relate sounds to meanings. This leads to a concern with phonological units within the grammatical system. However, grammatical systems describe properties of the sentences produced by speakers, and not properties of the speakers themselves. Accordingly, it would be a fundamental methodological error to assume that a system which correctly fits sentences must thereby correctly describe properties of the organism. The physiology of motor control mechanisms in speech articulation, on the other hand, allows the collection of data that are independent of formal linguistic considerations and also independent of specific language

systems. Thus, they provide a methodologically sound basis for evaluating the claims made by formal linguistics with regard to language universals as well as the phonologies of particular languages. This potentiality of physiological research with respect to linguistic theory is not fortuitous. Linguistic theory has increasingly directed attention to the organism: linguistic competence applies to the speaker and not to the sentences he produces. But the investigatory methods of formal linguistics do not incorporate either the variables or procedures required for these metatheoretic considerations. Accordingly, physiological research on language phenomena is a necessary condition for the evaluation of these aspects of contemporary linguistic theory."[1]

Finally, an understanding of the physiology of speech production is not only of theoretical relevance, but also has significant practical importance. There are many disorders of language which are primarily disruptions of the control mechanisms of speech output: the dysarthrias and motor aphasias being prime examples. Increased knowledge of these basic mechanisms should have important implications for therapeutic techniques used in the treatment of such disorders.

---

[1] C.I.J.M. Stuart, "On the Language of Linguistic Science", unpublished paper delivered to the Linguistic Association of Great Britain, Edinburgh, 1966.

II. REVIEW OF THE LITERATURE

Feedback in the production of speech originates from hearing and 'feeling' one's own vocal and articulatory speech output. The obvious components of the feedback are external path hearing (air), bone conducted hearing, internal vibration, tactile and proprioceptive sensation.

The recognition that aural self-monitoring is an important adjunct to the act of speaking developed slowly until the early 1940's when Georg von Bekesy (1942) published some of his pioneering work. Later, the work of Black (1951) and of Lee (1950 & 1951) demonstrated that a delay in the external auditory feedback produced an effect, mainly in terms of intensity, rate and fluency, on the speaker's performance. The fact that in such experiments the delayed signal is the air conducted component alone while the internal pathways remain unaltered has interesting implications. Stromsta (1962) noted that to produce the experimental effect the sound pressure level of the delayed external signal must exceed that of the unaltered internal signal. He concluded from this that both the external and internal pathways are of relative importance to the production of speech. Later investigators appear to have given little consideration to these factors although they are clearly of essential import in any attempt to mask the speaker's own voice.

It was clinically observed that such a delay, imposed upon the stutterer, caused relaxation of the characteristic blocking in his speech and induced a greater degree of

fluency (Van Riper, 1970). Cherry and Sayers (1956) discussed the effects of masking the various auditory feedback channels in relation to their studies of inhibition of stuttering. They concluded that elimination of air conducted feedback has little effect on the performance of a stammering subject. Blocking air and bone conduction pathways simultaneously, however, generally resulted in complete suppression of stammering.

For the most part, there has been a tendency to consider the effect of ambient noise on hearing acuity and this in itself has become a major field of enquiry (Miller, 1947). Measurements were made of levels of discrimination for one tone in the presence of another and of such phenomena as recognition of speech or patterns in the presence of various kinds of acoustic masking noise.

A considerable amount of work has been done connected with the observed increase of voice intensity in the presence of noise. Experimenters in this field span the years from Lombard (1911) to Lane (1971). Generally, they interpreted this effect as the attempt by the speaker to over-compensate for the ambient noise. In a recent review, Lane and Tranel (1971) interpret the increase in intensity in terms of the speaker's attempt to maintain intelligibility of verbal communication in the face of noise. However, Cherry and Savers (1956) have noted that some speakers spontaneously maintain normal or sub-normal voice levels during masking. This observation, plus the complexity of the phenomenon raises

serious doubts about Lane and Tranel's rather simple hypothesis - "...the speaker need no more listen to himself while speaking than he need speak to himself while listening." More significant, perhaps, is the fact that this hypothesis is inconsistent with the observed fact that people who cannot hear their own speech (the deaf) are unable to maintain normal speech production for very long.

The variety of approaches in masking studies has perhaps clouded an important consideration. It is the question of whether or not aural self-monitoring of speech (through external or internal pathways) is merely an epiphenominal adjunct to the speech act, or is in fact an essential component of sensorimotor control of speech. Viewing the Lombard sign (i.e. gradual increase in vocal intensity during a similar increase in masking intensity) (Lombard, 1911; Miller, 1947) as a non-specific phenomenon may explain why several authors have dismissed the role of auditory feedback as relatively unimportant compared to tactile and proprioceptive feedback (Lane & Tranel, 1971; Gammon et al, 1971).

A possibility which has not been discussed in the literature is that the observed effects upon motor output may, in fact, be the result of the noise input, the masking noise itself creating a disturbance of system efficiency. In this respect, we should note that in experiments where two or more sensory channels are simultaneously inhibited (Ringel & Steer, 1963; Gammon, et al, 1971; Silverman & Goodban, 1972) the contribution of individual components may have been confounded.

In view of this, it is necessary to look at the available literature in two separate ways. First to review the type of auditory masking which has been used, and its efficiency in inhibiting self-monitoring of speech. Secondly, to discuss the effects reported and how the measurements of these effects have been interpreted.

Part I.

Masking experiments have mainly been conducted as part of a larger plan, e.g. with topical anaesthesia and nerve block treatments as added conditions. Masking has also been used as a method for investigation of the characteristics of stuttering (Cherry & Sayers, 1956; Burke, 1969; MacCulloch et al, 1970; Silverman & Goodban 1972). In these studies the masking noise itself has been consigned only a minor role in the experimental design. The actual acoustic details of the masking noise - its amplitude, spectrum, and effectiveness in covering the vocal characteristics of the subject, have often not been a major focus of concern. There are obvious limitations to the interpretation of data obtained from experiments whose treatment plans do not take account of variations in these parameters.

Where the purpose of the experiments has been to block the speaker's awareness of his own voice, almost all experimenters have used white noise masking. Miller compared different types of masking and their effectiveness but principally for masking independent noise signals (Miller, 1947). He discussed pure tone, narrow band, wide band,

white noise, filtered noise, voices, and music, as masking agents. His conclusions, however, should also be relevant to the problem of feedback masking. He stressed that the matching of the spectrum of the masking sound to the spectrum of the signal was of utmost importance. The experiments he reviewed mainly involved the perception of an external signal under conditions of monaural or binaural masking, testing response to both "background noise" and to interference. In his report of experiments using music as a masking agent, Miller made an observation which does not appear to have been expanded upon or further investigated within the context of masking experiments. He stated: "A very complex masking sound is obtained, however, if two or three phonographic recordings are played at the same time. The different orchestras fill in each other's pauses, and the coverage of the speech frequencies is more consistently adequate." (p. 112).

Subsequently to Miller's studies, less emphasis has been placed upon various methods of masking the acoustic signal. In the investigation of motor control mechanisms in speech we typically find that more than one feedback system has been inhibited during the course of one experiment. Auditory inhibition, therefore, became one treatment of several conditions and the acoustic details of the masking sound, and the accompanying complex effect upon the subject, has received little attention. This, in turn, has led to diminished consideration of the ethical issues regarding

intensity levels of masking.

Illustrating this point is the work of Black (1951) who subjected 144 college students to two hours of noise at 110 dB (SPL). He then measured the temporary hearing loss induced, and the increase in the subjects' voice levels during reading of sentences. Hanley and Steer (1949), cited by Lane and Tranel (1971, p.684) also used excessively high intensities: 5 dB increments from 100 dB to 130 dB, while measuring voice level increases in noise compensation experiments. Gammon et al (1971) used 110 dB white noise during a multi-sensory blocking experiment. During this time, interesting physiological experiments have exposed cats, for example, to lengthy periods of intense noise, later revealing gross inner ear changes, which would certainly not be described as 'temporary' (Bredberg et al, 1970). Standards regarding exposure to noise have been legislated in many countries.

The authors who used high intensity levels were no doubt attempting to overcome the known difficulty that a speaker is well able to hear himself speak until the masking sound exceeds the perception of the internally conducted speech wave form. It is important, nevertheless, to be aware, as was Miller (1947), that neither pure tones nor white noise, however loud, cover the entire spectrum of the internal speech wave form.

Cherry and Sayers (1956) endeavoured to mask both air and bone conducted feedback with a pure tone, and found that the loudness of the masking tone had to be "close to the threshold of pain" (p. 239) to achieve complete masking. They were aware of the uncertainty that their subjects were indeed completely masked. In fact, their results caused them to continue with a further experiment using white noise instead of the pure tone, "with its more highly concentrated energy". The white noise also approached pain level and the results revealed the interesting observation that, for stutterers at least, it was essential to mask the very low frequency tones of speech, or stuttering would remain. The authors proceeded to use filtered noise to try to achieve this aim.

Ringel and Steer (1963) chose their subjects for auditory, tactile and proprioceptive masking experiments from female students majoring in speech pathology and audiology. They used binaural white noise at 94 dB (re. 0.0002 dyne/cm^2). Apparently they did not consider the possibility that their subjects might still be aware of their own voice with the level and type of masking used. They did not describe any method of ascertaining the speakers' auditory awareness, and the minimal effects upon speech output which they obtained suggest the possibility that their subjects were not effectively masked.

Gammon et al (1971) used eight subjects for an experiment involving tactile, proprioceptive and auditory

inhibition. They used 110 dB SPL (re. 0.0002 ubar) white noise for binaural auditory masking. Again the auditory masking agent chosen, white noise, is the easiest to produce, but it is not easy to analyze results obtained due to the lack of assurance that the subjects actually experienced total inhibition of auditory feedback. The very high intensity used is perhaps an indication that the authors were aware that the white noise might not adequately mask their subjects, but no reference is made to this problem.

Other experimenters have reported unspecific auditory masking techniques. Ladefoged (1967) describes an "informal" experiment in which "the intensity of the (masking) noise was adjusted so that the subject could not hear his own voice even by bone conduction." A 300 Hz. pure tone was used by MacCulloch et al (1970) at an intensity "sufficient to render the subjects' own speech inaudible." The subjects were children and they were instructed to set the power control themselves by indicating when the next set of discrete sound pips would be "intolerably loud". Silverman and Goodban (1972) used white noise of 94 dB SPL to mask twenty undergraduate students, twelve males and eight females. Seemingly, no control for the differences in the vocal quality and character of males and females was made. The lower fundamental frequency of the normal male voice could readily have resulted in substantial sound energy being present below the frequency of the masking sound. It seems unlikely, therefore, that the same level of masking

effectiveness was achieved with the male subjects as with the females. Sussman and Smith (1971), in experiments involving delayed auditory feedback, set the playback intensity of the delayed signal "high enough to mask the actual voice of the speaker and any possible bone conducted feedback." No evidence was given either as to the masking effectiveness or the intensity employed.

Some inconsistencies and important ambiguities can be discerned in all these experiments. Whether or not the auditory masking agent was as effective as the analysis of the results assume is a major question. The fact that the intensities used have so often exceeded reasonable standards of ethical procedure is of great importance and relevance in the planning of future experiments. Using human beings in experimental research imposes limits within which the physiological conditions of the experiment must remain. There is an abundance of literature reporting on noise exposure and associated hearing loss, especially with reference to industrial safety measures. It is clearly incumbent upon experimenters to remain within established standards.

Part II

The previously quoted literature falls into two distinct groups.

(i) In the first group investigators have used auditory masking as one part of a multivariate experiment which also involved inhibition of tactile and proprioceptive feedback.

The experimenters have collected a large amount of data which demonstrated disturbance of voice and articulatory characteristics. They correlated such variables as pitch change, peak intensities, misarticulations, voice quality and rhythm, mean syllable duration, and vowel length. The general conclusion in the majority of these studies was that auditory feedback disturbance causes some disruption to a variety of speech output characteristics in normal speakers. There is also general agreement that when two feedback systems are disturbed at the same time, the disruption to articulatory precision and speech quality increases. However, we find papers which report auditory masking as being effective but which do not specify the intensity levels and spectral characteristics of the masking sound. Others report intensity levels but not spectral characteristics or apparent masking effectiveness. Spectral characteristics have particular significance, for example with regard to the sex of the speaker, under auditory feedback masking, but little or no attention has been paid to this factor in this first group of experiments.

(ii) In the second group, investigators have generally used auditory inhibition as the main experimental condition. This has led to a more concise description of the actual techniques of masking.

Cherry and Sayers (1956) reported experiments on inhibiting stutter by different techniques. They found it necessary to mask bone-conducted auditory feedback in order

to reduce the low frequency components of speech which were known to be monitored through bone conduction pathways (von Bekesy & Rosenblith, 1951). They concluded that certain stimuli were "undoubtedly the larynx tones of the speaker". They experimented with pure tone, white noise, and filtered noise as masking signals. Unfortunately, they did not describe their instrumental design in detail nor did they give precise intensity levels, reporting only that the masking sound approached pain level.

Miller (1947) made several important observations concerning both the techniques of masking and the effectiveness of different acoustic masking signals. He was aware that the masking noise must be uninterrupted, and stated: "any periodic interruption of a masking sound lowers it's masking effectiveness." It should also have a concentration of power in the low frequency range if it was to "seriously mask" human speech. It followed from his study of various masking experiments that the "optimal masking noise has a spectrum similar to the long-interval speech spectrum which is being masked."

The more recent work of Stromsta (1962; 1972) implies that speech variations induced by auditory masking are possibly peripheral reflections of a "control or synchronizing system". The hearing of one's own voice would be a crucial part of such a system. Stromsta uses the term "sidetone" to refer to auditory feedback signals received by the speaker via essentially laryngeomandibular pathways. His numerous

measurements of phase and conduction velocities indicate important relations between air and bone conduction pathways. He suggests that the control, or synchronizing, system may involve "(i) a neuromuscular initiation and effector portion, and (ii) a sensory feedback portion." The sidetone would evidently serve as a factor in the sensory feedback portion. Stromsta argues that his research into the nature and function of these sidetone pathways has shown that the laryngeal tones are an important component of auditory feedback (Stromsta, 1972). If so, masking of the laryngeal tones may be required for effective inhibition of auditory feedback.

Sussman and Smith (1971) studied the effect of delayed auditory feedback upon the dynamics of jaw movement in speech production. They concluded that "the speech motor system is intricately synchronized with the temporal patterning of the auditory feedback of speech".

In summary, prior to about 1970 experimental results tend to be interpreted as indicating that auditory feedback does not play a significant role in contributing to motor control mechanisms in speech production. Since 1970, we find a tendency in the opposite direction; however, neither the nature of the disturbance to speech caused by auditory masking or the requirements for effective masking have been worked out.

There is fairly general agreement that auditory masking does cause some disturbance to speech output. The increase in intensity of the voice has been often noted, though little significance has been attached to this phenomenon.

Other disturbances have been reported by individual authors but these have not been well characterized. These have included changes in fundamental frequency, pitch, and speech rate. It is known that the auditory-masked speaker tends to alter vowel length, to slur, and to omit or substitute syllables and consonants. Implicit in the literature, but not discussed in depth, is that the disturbance to speech is highly variable from one utterance to another and, perhaps, from one speaker to another. The importance of the sidetone pathways to the acoustic feedback mechanisms has been argued though not closely followed up. The sidetone pathways clearly include laryngeal contributions to internally conducted hearing, but possible laryngeal contributions to proprioceptive feedback should not be overlooked.

With regard to the masking signal, it is acknowledged that in the case of delayed auditory feedback the intensity of the delayed external signal must exceed that of the unaltered bone-conducted signal. White noise has been found to be more effective than pure tones in masking speech, and some authors have emphasized the importance of masking the low frequency components of the subject's voice. But, in spite of the considerable number of reported studies in this field, there is no agreed criterion or method for effective auditory masking of the speaker's own voice. No agreement has been reached regarding the intensity or frequency spectrum of noise to be used. The role of the pathways conducting auditory stimuli internally from the larynx, for example, has not been controlled or accounted for in any system of masking the

speaker's own auditory feedback.

Thus, quite fundamental questions concerning the role of auditory feedback in the production of speech remain open. While information does exist in the literature to suggest that it may be important, the experimental data do not provide an adequate basis for detailed conclusions. Important parameters for consideration are the feedback integrator, which receives feedback as input, and the final motor output control system ultimately reduces to these parameters. But the full significance of these parameters is likely to remain obscure until we have improved methods of auditory feedback inhibition.

CHAPTER TWO

EXPERIMENTAL OBJECTIVES

As indicated in the Introduction, speech control mechanisms provide a significant instance for two problems in neuromuscular physiology:

(1) whether control in the case of skilled, rapidly alternating, and finely adjusted movement depends on open or closed loop systems, or a mixture of both,

(2) whether the motor control mechanism of the cranial neuromuscular system parallel those found in the skeletal muscles.

In addition to these problems of current physiological interest, there is the further significance for physiology, as well as for purely linguistic inquiry, arising from the motor activity of speech having to be in accordance with a predetermined plan that involves the coding, at different neurological levels, of information extending from cognitive intensions to the final motor execution. Speech production is thus a complex, hierarchically organized, phenomenon involving a number of neurological levels.

Thus, the fact that auditory feedback (AF) is present during normal speech production does not admit any simple, prima facie, interpretation. An AF loop could be closed at one or more neurological levels, or it could be that AF is an incidental epiphenomenon with respect to the entire range of functions that underlie speech production.

The presence of AF certainly prevents us from treating the speech production mechanisms as a straightforward phenomenon with respect to problems of modern physiological interest such as (1) and (2) above. Because of this complication relative to control mechanisms in the skeletal muscles, it is necessary to assess the contribution of AF before we can investigate the speech control mechanisms in terms of problems like (1) and (2).

In principle, we should expect that analysis of effects obtained under AF inhibition should throw light on the neurological levels that normally depend on AF. The currently available evidence, however, makes it difficult to undertake such analysis. Published reports indicate only slight changes in speech during presumed AF inhibition, speech output remaining highly intelligible. On the face of it, these reports would preclude any major contribution of AF to critical control parameters at any level of neurological function, thus supporting the view that AF constitutes an epiphenomenon of little or no functional significance. However, the characteristic dependence on white noise as a masking agent makes interpretation of the data a difficult task for two reasons

(a) The slight effects on speech output may be due to failure to achieve AF inhibition in experiments where the white noise used was a weak masking agent relative to the spectral characteristics of the AF.

(b) In other experiments, where total AF inhibition is claimed, white noise intensity may have been at a sufficiently high level to introduce a confounding of AF inhibition with a general, non-specific, stress phenomenon. Even a completely open loop system might exhibit oscillation under a generally disturbing sensory input.

In view of the above considerations, the primary objective in the present study was to develop a well defined technique which is effective in producing AF inhibition without introducing a strongly noxious stimulus.

In order to meet this joint objective, the same intensity level was used for white noise and autogenic masking. Thus, questions related to non-specific stress and to speech disturbances observed during masking treatments are referred to a single sound intensity level.

If, at the same intensity, autogenic masking is at least as effective as white noise masking in producing AF inhibition, while at the same time autogenic masking is less stressful to subjects than white noise masking, then the primary objective may be said to have been achieved with the consequence that speech disturbances observed under autogenic masking can be analyzed with improved confidence as to their relevance to phenomena of sensory inhibition.

The data recorded in the present study permit

analyses of the kind made by earlier investigators: fundamental frequency distribution, speech rate, phonation time ratios, etc; voice intensity distribution is precluded because of our attempt, described in Chapter Three, to prevent overloading the recording apparatus.

A large range of articulatory variables has been implicated, with varying degrees of consistency, in auditory masking experiments. However, it has not generally been possible to predict on theoretical grounds which variables should be affected by auditory feedback masking. Further, consistent analysis and interpretation of speech changes observed under auditory masking is made difficult by differences in experimental conditions, as well as the focus of attention, between different investigators. In general, the selection and quantification of speech parameters in relation to problems of sensory and motor physiology is a topic that needs major review.

For the immediate purposes of this thesis, attention was restricted to certain articulatory changes noted during the pilot experiments and apparent laryngopharyngeal tension assoicated with changed voice quality. This does not appear to have been reported in previous studies of auditory masking, though during the preparation of this thesis Ringel et al ii (1973) reported added

frequency components in the speech of subjects under topical anaesthesia of the oral mucosa.

CHAPTER THREE

Experimental Methods

1. Design

Three types of speech output were obtained from four adults and from four teenage female subjects under a control condition and four conditions designed to mask auditory feedback.

(i) Speech elicitation procedure

The three types of speech output were chosen to represent a range from relatively automatic to propositional speech. On the basis of widely held clinical opinion, completely automatic speech might show more resilence to sensory inhibition than would propositional speech. However, there are difficulties in the experimental use of completely automatic speech due to intrinsic habit patterns associated with such speech articulation. For this reason, subjects were asked to read aloud a standard ten-sentence passage of prose to represent a speech form that is relatively automatic compared with fully propositional speech. To represent propositional speech, the subjects were asked to respond orally to questions presented in written form, and also to describe scenes presented in a set of pictures. This material is contained in Appendix A.

The speech elicitation procedures were introduced in a fixed order:

1. Seven written questions requiring a one-sentence oral

response.

2. A ten-sentence prose passage to be read aloud.
3. Visual presentation depicted in four different pictures, the scenes to be described orally.

The question answering, as one form of propositional speech was presented first to absorb any early tension in the subjects and to permit initial adjustment to the masking noise. The relatively automatic speech obtained from reading aloud was expected to be least disturbed by masking; but since this form of speech would provide the only basis for true replication across subjects, it was introduced after initial adjustment as the primary data source. The second form of propositional speech, oral description of scenes, was elicited last.

(ii) Masking procedures

The above procedures were followed under two conditions of binaural auditory stimulation intended to deprive the subjects of AF during their speech production. The first masking noise consisted of white noise at 85 dB above the individual subject's hearing threshold. The second, autogenic masking, applied at the same intensity level, was obtained from a reverse playback of four superimposed passages read aloud by each subject thus obtaining a masking agent sensitive to the spectral characteristics of the individual subject's voice. Two additional conditions were introduced by repeating the above conditions while simultaneously applying the masking signal to the larynx via an external

vibrator. In order to restrict the length of the experimental sessions, only the oral reading was elicited from the subjects for the two conditions involving the laryngeal vibrator. As a control condition, the speech elicitation procedures were followed but without the application of a masking signal.

Thus the following conditions were involved:

I. (A) Binaural application of white noise signal.
   (B) Condition I(A), plus white noise applied to the larynx.
II. (A) Binaural application of autogenic noise signal.
   (B) Condition II(A), plus autogenic noise signal applied to the larynx.
III. Control Condition.

The non-masking or control condition was applied last so that any fatigue effects would be less likely to occur under the masking conditions. A random draw was made for each subject individually to determine the order in which the masking conditions, white or autogenic noise, were to be administered. Whichever type of noise was selected, binaural administration was followed by binaural plus laryngeal application of the same masking source; the same order was then maintained, binaural followed by binaural plus laryngeal, for the second masking noise.

The experiments reported here were frankly exploratory in character; within the framework of the above design features, we hoped to collect data relevant to the following

questions.

1. Is there evidence of effective AF inhibition at a comfortable level (85 dB above threshold) of masking noise?
2. If AF inhibition is achieved, is there evidence of associated change in speech production?
3. Are there differences in the above effects that can be associated with differences in the masking conditions employed?

The data utilized in the attempt to answer these questions were drawn in part from the speech output of the subjects under the conditions summarized above; details of these data and their analysis are presented in Chapter Four. In addition, introspective reports were obtained from the subjects following completion of the experimental sessions. These reports concerned qualitative reactions to the experimental procedures and were intended to provide data relevant to the effectiveness of the masking conditions in inhibiting AF and to the evaluation of non-specific stress factors that might influence the interpretation of the speech output data. Further details of these reports are provided later in this chapter, in section 3(iii), and in Chapter Four.

2. Subjects

A total of ten female volunteer subjects took part in the experiments. Six were adults who ranged in age from 19 to 34 years. Four subjects were high school students aged 16 years.

All subjects were native speakers of North American English. Each had speech which by standard clinical criterion fell within the normal range, and each had normal hearing acuity ascertained by the testing procedures described below.

Two of the adult subjects were used in preliminary experiments; their data were excluded from the final comparisons because of differences in conditions administered to them as compared with the fixed conditions applied to the remaining subjects. Thus, the subjects fall into two groups of four, and are distinguished by adult versus teenage status.

3. Apparatus and Procedures

(i) Experimental arrangement

The laboratory was furnished with a dental chair fitted with a head rest which maintained the subject in a relatively fixed position for the experiment. The chair was so positioned that the experimenter could work behind the subject and so that the subject was unable to see the instrumentation. A small table in front of the subject held the instructions and speech elicitation material supported on an easel. Beside this was a box with a small red neon lamp. Circuitry in the box triggered the light if the intensity of the subject's voice caused the V-U meter of the data tape recorder to exceed its reference level. The recording level was set during normal speech before the commencement of the experiment. Gross increases

in intensity would seriously overload the tape recorder and cause unsatisfactory data recordings. The device was used to counteract this problem. An adjustable stand mounted on the table held a Sennheiser, Model 421 N, microphone. This was positioned approximately twelve inches from the subject's mouth. For the experiment in which the laryngeal vibrator was used, the table served as a stand for a magnetic clamp to which the vibrator was attached.

The masking noise was presented through Telephonics, TDH 39 earphones, installed in an Auraldomes Aural Research headset. The earphones were driven by a Braun, model AG type CSV 250, power amplifier the output of which was monitored with a Hewlett-Packard, model 400 E, A.C. volt meter. An attenuator was incorporated in the line between the amplifier and the earphones. A 2-position switch selected zero or 63 dB attenuation. The attenuation position was used to reduce the sound intensity for the testing of the subject's hearing threshold without interference from background noise originating in the amplifier. The masking signals were obtained from a Braun, model TG 504, tape recorder, using, appropriate tapes. In those experiments where the laryngeal vibrator was used, a shaped plastic pad was held in contact with the subject's neck in the region of the thyroid cartilage. A thin stainless steel rod (5 1/2" in length and 3/16" in diameter) connected the pad to a Bruel and Kjaer, model 4810, Mini Shaker, having a frequency range 20 Hz to 18 k Hz. The shaker was driven by the same

signal as the aural masking through a second Braun, model AG type CSV 250, power amplifier, having a frequency response of 40 Hz. to 15 k Hz ± 1 dB. The speech output was recorded on a Teac, model A-7030 tape recorder, at a transport speed of 7 1/2 inches per second.

(ii) Stimuli

Two different tapes were used for the auditory masking signal. The white noise tape was recorded using the signal from a model 1382, General Radio Random Noise Generator. An autogenic noise tape was made for each individual subject. The subject read four different passages of prose, each of varying style and of about five minutes duration. These were all recorded on the same audio tape track, one superimposed on the other. The recordings were made in a sound proof booth, using a Teac, model A-7030 tape recorder, transport speed 7 1/2 inches per second, and a Sennheiser, model 421 N microphone. Later, when used for masking, the autogenic noise tape recording was played backwards.

In addition, a tape was prepared of 1 k Hz. pure tone used for determination of the subject's hearing threshold.

(iii) Experimental procedure

An experimental session was held separately for each subject, lasting approximately two and a half hours. The first task was the recording of the autogenic noise tape, as described above. The subject was then seated in the dental chair and the experimenter explained the procedure, allowing the subject to become accustomed to the chair and

to the general laboratory environment. Care was taken to explain the purpose of the experiment as simply as possible. Prior to the experimental session the subject had been told that we were interested in recording people speaking under different types of noise conditions. In the laboratory this statement was repeated. No suggestion that speech might be altered by such a procedure was made. The particular steps in the procedure were explained carefully. Thus the risk of response bias resulting from the subject's awareness of what they were doing was assumed to be minimized.

A measurement of the subject's hearing threshold was then made in the following manner. The subject was asked to listen to discrete pips at 1 k Hz. played loudly through the Auraldomes earphones, but with the headset still on the table. This was simply to familiarize the subject with the type of sound to expect and to facilitate the explanation of the test. It was then explained that the subject would, when the headphones were set on the head, hear three faint pips in one ear. When the subject was able to barely hear the tones, but recognize the three pips, she was asked to indicate that she had heard them. The earphones were then set comfortably on the subject's ears, and using the attenuator and the volume control on the Braun amplifier, each ear was tested consecutively and the output level at threshold measured on the A.C. volt meter.

At this point in the experiment, the subject was given a break for coffee, and was encouraged to freely discuss any anxiety that she might feel about the surroundings or the

procedure.

Returning to the laboratory, the subject was again seated in the dental chair. The experimenter then determined the sound level for masking by first averaging the measurements taken for each ear. This average was taken as the subject's threshold and the masking level adjusted with the amplifier volume control so that the A.C. volt meter read 85 dB above this value. This level was used for both types of masking and continuously monitored on the volt meter.

The type of masking noise, either white noise or autogenic noise, chosen for the first condition was selected randomly. The control condition was always the last. To facilitate analysis of the data, the data tapes were blocked out to permit the same ordering of conditions on each subject's speech output tape. The subject was given careful oral instructions concerning the red light beside the easel. She was told that the red light would flash if she was speaking so loudly that it would be difficult to make a good recording of her speech, and that it would simply remind her to lower her voice. No further emphasis was placed on the intensity control device.

We were aware of disadvantageous side effects of the red light. Silverman and Goodban (1972) introduced three lights, for example, which would seem to encourage the use of a continuous monotone by the speaker. To avoid this, one light only was used to prevent overload on the system due to sudden increase in vocal amplitude. Obviously, this

prevented any accurate measurement of the Lombard Sign, but as that effect has been well-documented in the past (Lane and Travel, 1971), the decision to obtain as good recordings as possible was made at the expense of data relevant to voice intensity changes.

Oral instructions were given initially about the material presented for reading and for propositional speech; also, prior to the commencement of each section of the material, the instructions were presented visually (Appendix A). The material was always presented in the same order, as described earlier in this chapter. As the passage of reading would be used primarily for the data analysis, this was presented after the questions in order that the subject might have some minutes to adapt to the masking noise, and for any sudden tension effects to have subsided. On the other hand, we had considered the possibility of fatigue effects, and to counteract this the subjects were given a break between each condition and were encouraged to talk without the masking sound disturbance.

After the verbal instructions, the earphones were placed on the subject's ears in readiness for Condition A. The masking noise was presented binaurally at the previously calculated intensity, 85 dB above the individual hearing threshold for the particular subject. After the correct setting was established the experimenter signalled the subject to begin by turning the page of instructions to the first section (the questions). Thus, there was a 5-10

second presentation of the masking noise prior to the subject commencing to speak.

After a brief, one to two minute, rest we continued with Condition B. The laryngeal vibrator was attached to the table, using the magnetic clamp, and the angle adjusted so that the shaped pad came in contact with the subject's neck. A resting position against the headrest of the chair maintained the subject's head in a stable position and the vibrator pad was then positioned carefully against the thyroid cartilage region of the neck, thus ensuring a relatively constant pressure. For Condition B, the subject was requested to read the prose passage only. The masking noise was then presented in the same manner as for Condition A through the earphones, and also through the laryngeal vibrator. Exactly the same procedure was followed for the second masking noise. The control condition, III, was conducted in the same way, with the subjects seated in the same position and reading the same material, but there was no masking sound present.

Following completion of the experimental procedure each subject was asked questions concerning her subjective reactions to the experiment: (a) was she able to hear herself speak? (b) which masking noise was preferable, and why? (c) which was most effective in preventing her from hearing her own voice? (d) was she aware of any difficulty in speaking at any time during masking? (e) were any of the masking conditions especially notable in this respect? She

was also asked about the laryngeal vibrator and whether this had been disturbing, whether it had masked her voice more effectively than the simple binaural masking, or made no difference. Finally, she was asked if the loudness of the masking noise had been uncomfortable in any way.

(iv) Data recording and analysis

As indicated at the end of Chapter Two, the pilot experiments had revealed changes in voice quality associated with an apparent laryngo-pharyngeal tension under AF masking. Since this had not been previously reported, we decided to restrict attention to analysis of the frequency spectra in order to obtain physical evidence of these changes. The primary instrumentation for the physical analyses is described below.

Sound spectrographs were made from the data tapes using a Kaye, model 6061-B Sona-Graph fed from a Teac, model A 7030, tape recorder. Both complete displays and sections (frequency spectra) were made. The following settings were used uniformly throughout, unless stated otherwise: linear scale; calibration select, 500 Hz.; record range, 80 Hz - 8 k Hz.; wide band; H-S switch (providing a high frequency pre-emphasis in the record circuits). Sections were taken to give an amplitude versus frequency display at a preselected point in time. The Sona-Graph settings for this were the same as for the full displays, except that the Sectioner was activated and the band selector was set for narrow band analysis.

High speed ink recordings were made to illustrate variations in high frequency speech components. Three channels of a model EM 34 Mingograf were used in conjunction two Frøkjaer-Jensen Electronics intensity meters and a type 400 Audio Frequency Filter to isolate the high frequency components. The signal was obtained from a Teac tape recorder and recorded unfiltered on one channel, and after high-pass filtering on the other. The third channel traced the fundamental frequency of the subject's voice, the data recording passing from the Teac tape recorder to a Trans Pitch Meter and into the upper channel of the Mingograf recorder. A paper speed of 50 mm/sec was used throughout. Studies were made of various representative sections of the data by high-pass filter settings ranging from 3.9 k Hz. to 8 k Hz. Later recordings were made with the filter set at three different settings 3.9 k Hz., 4.7 k Hz., and 5.6 k Hz.) for comparison.

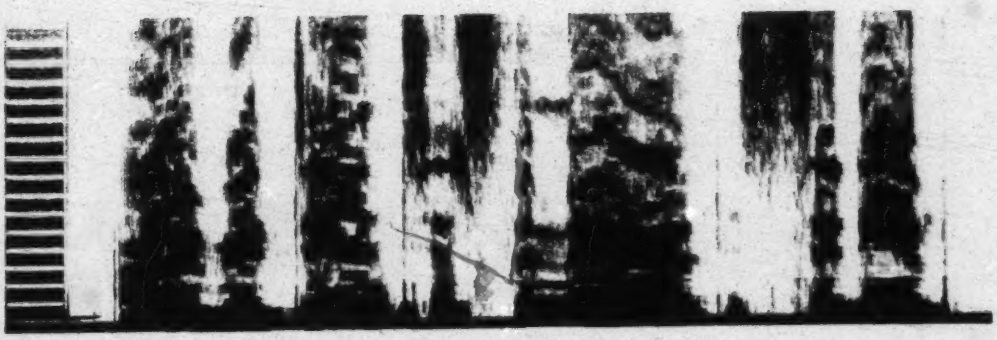
The laryngeal vibrator created a significant amount of noise which was detected by the microphone and appeared on the data tapes. While the subject's speech output is intelligible, the interfering noise is clearly audible, and therefore no instrumental analysis was made of the data from the B. conditions.

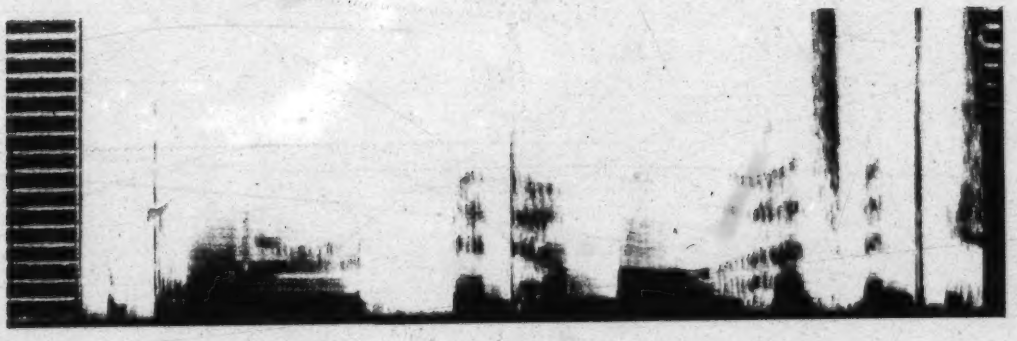
FIGURES

FIGURE 1

Sound spectrographs of typical additional formants and vocal fry.

Subject:	N.N.
Upper spectrograph:	illustrating the phrase "Ivor Dent is the mayor of the city" under speech-noise masking.
Middle spectrograph:	phrase, "poor and humble husband" in the absence of masking
Lower spectrograph:	phrase, "poor and humble man", illustrating vocal fry preceding the word "man".





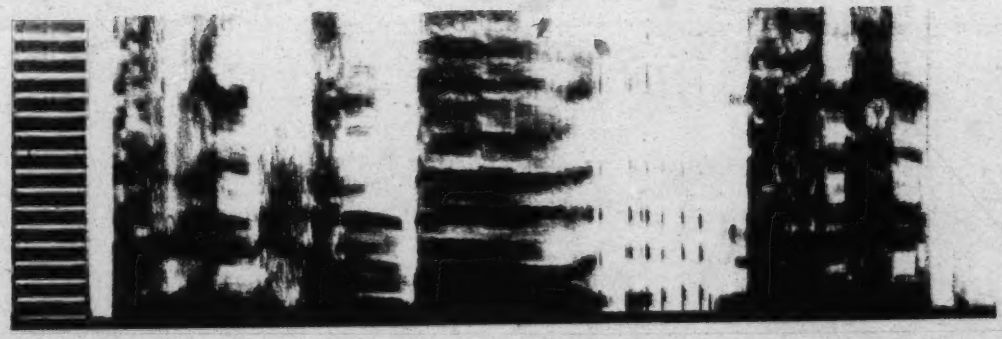
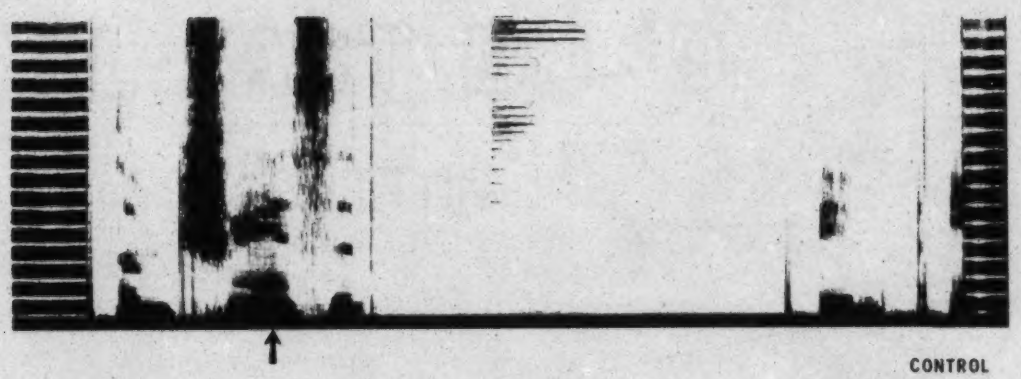


FIGURE 2

Sound spectrographs of the word "trees", part of the phrase "some trees that overhung a cool stream". A section of the frequency spectrum of the vowel sound /i/ in "trees" is seen to the right of each display, and the point at which the section is taken is indicated by an arrow.

Subject: P.K.

Masking conditions as indicated.



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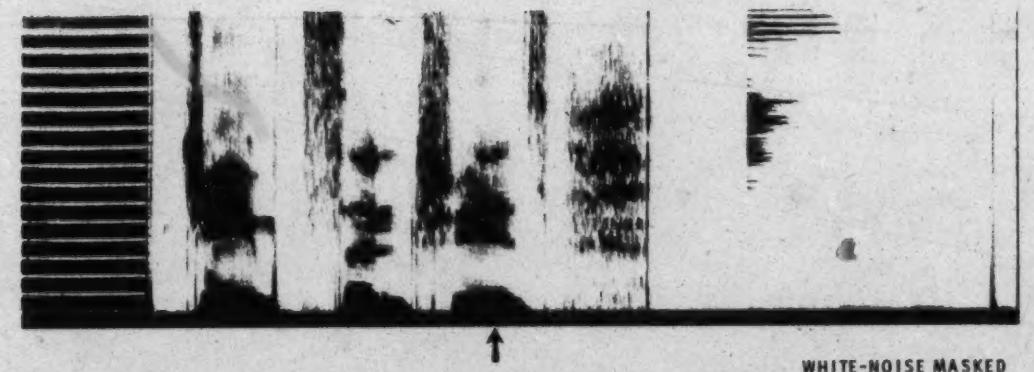
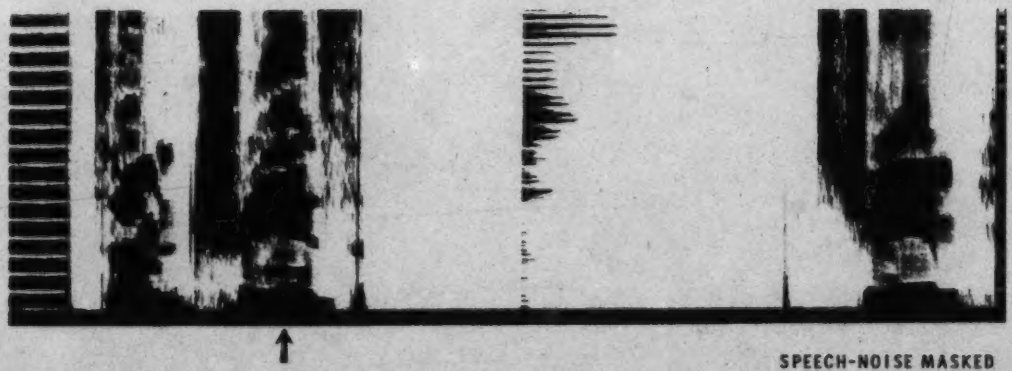


WHITE-NOISE MASKED



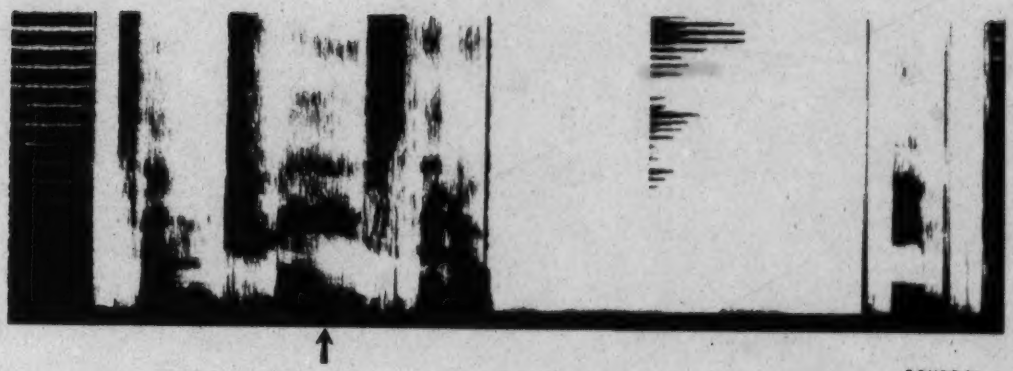
SPEECH-NOISE MASKED

FIGURE 3

Sound spectrographs of the word "trees", part of the phrase "some trees that overhung a cool stream". A section of the frequency spectrum of the vowel sound /i/ in "trees" is seen to the right of each display, and the point at which the section is taken is indicated by an arrow.

Subject: N.N.

Masking conditions as indicated.



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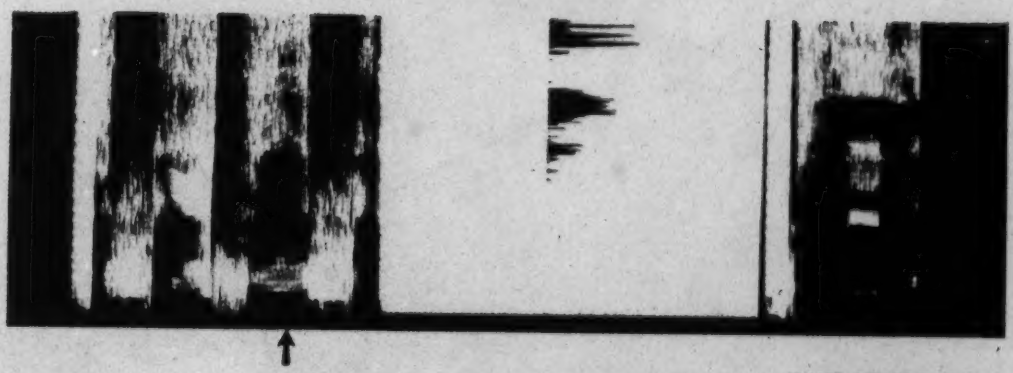

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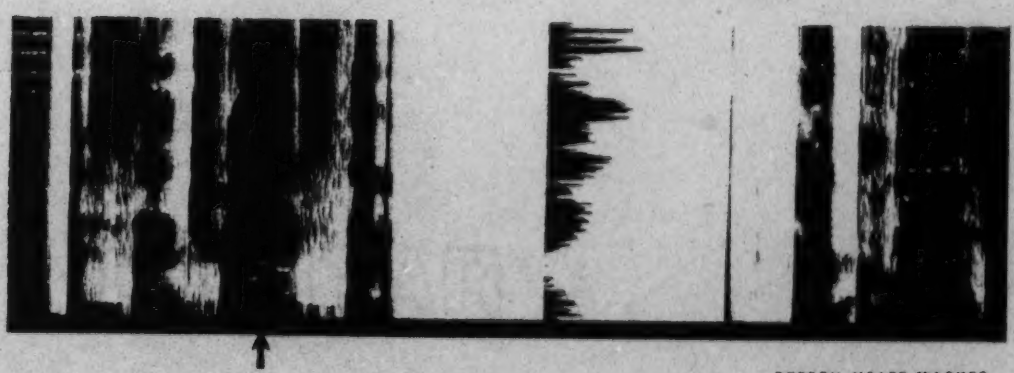


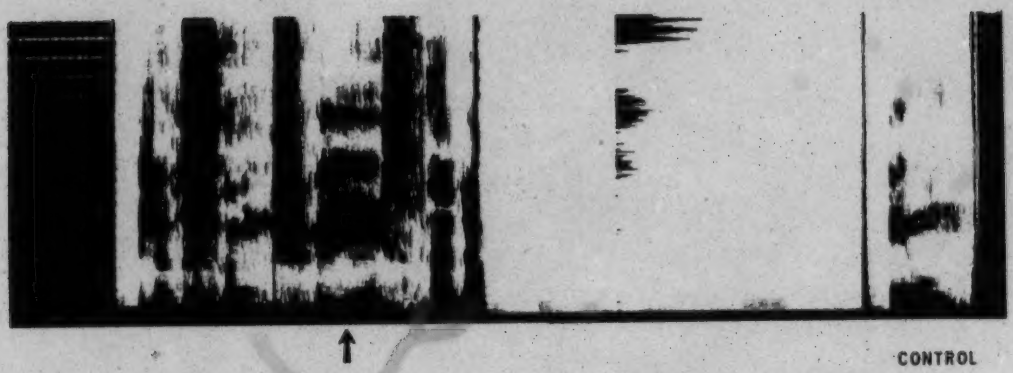
SPEECH-NOISE MASKED

FIGURE 4

Sound spectrographs of the word "trees", part of the phrase "some trees that overhung a cool stream". A section of the frequency spectrum of the vowel sound /i/ in "trees" is seen to the right of each display, and the point at which the section is taken is indicated by an arrow.

Subject: K.S.

Masking conditions as indicated.



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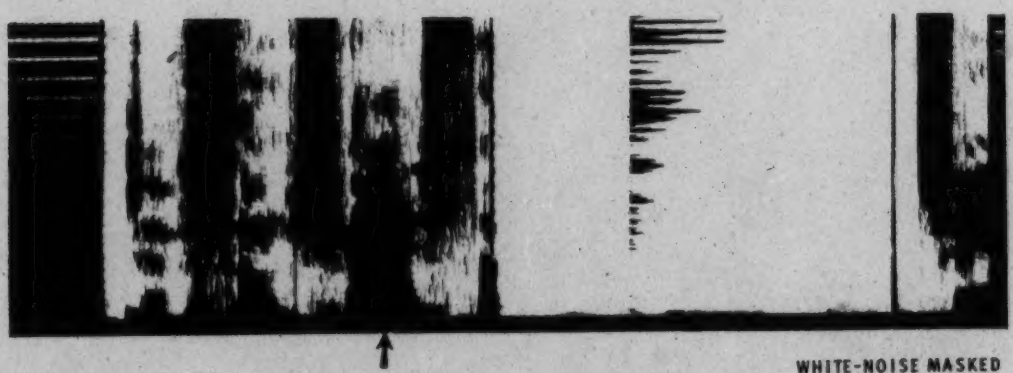

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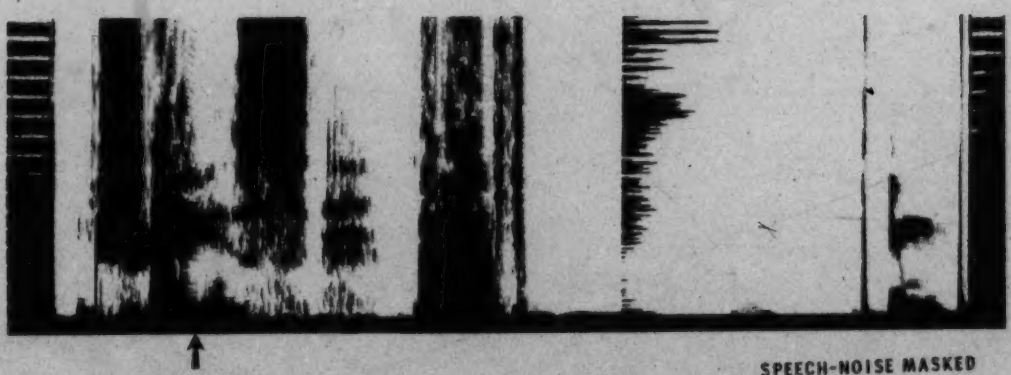


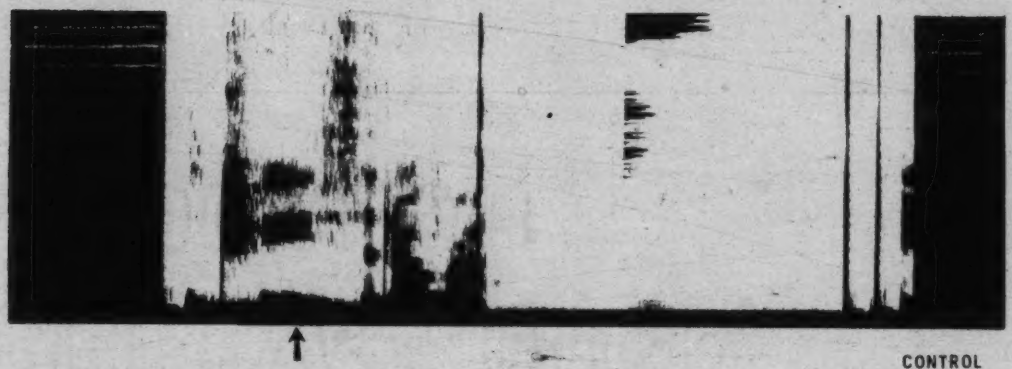
SPEECH-NOISE MASKED

FIGURE 5

Sound spectrographs of the word "trees", part of the phrase "some trees that overhung a cool stream". A section of the frequency spectrum of the vowel sound /i/ in "trees" is seen to the right of each display, and the point at which the section is taken is indicated by an arrow.

Subject: L.R.

Masking conditions as indicated.



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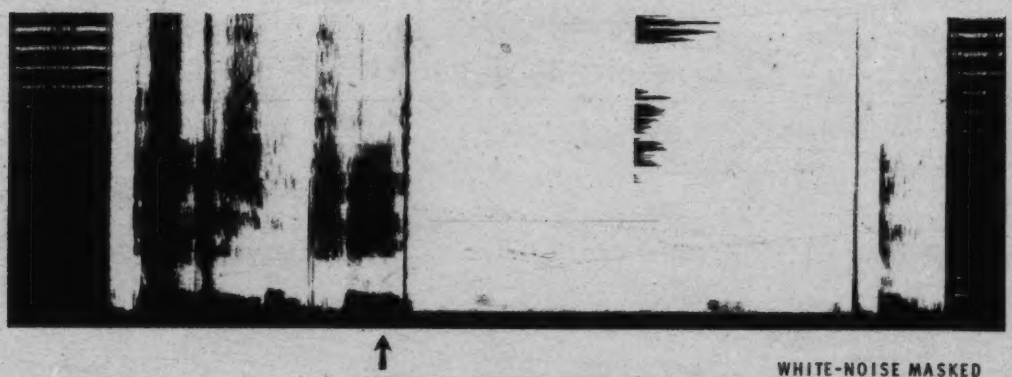

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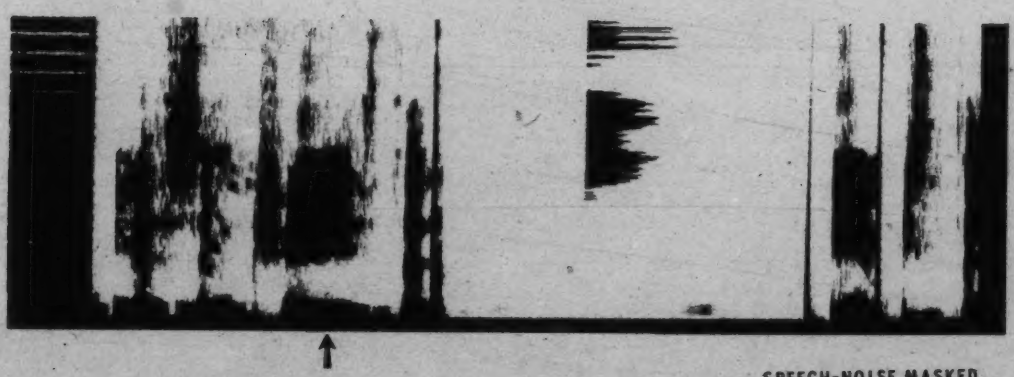


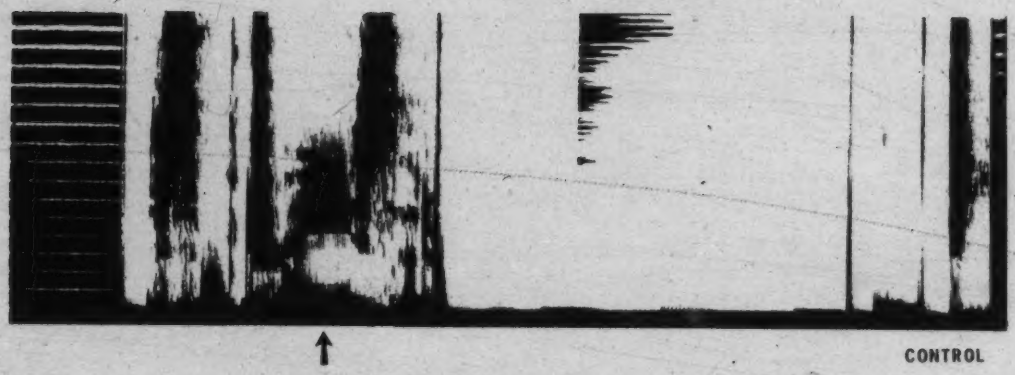
SPEECH-NOISE MASKED

FIGURE 6

Sound spectrographs of the word "trees", part of the phrase "some trees that overhung a cool stream". A section of the frequency spectrum of the vowel sound /i/ in "trees" is seen to the right of each display, and the point at which the section is taken is indicated by an arrow.

Subject: C.N.

Masking conditions as indicated.



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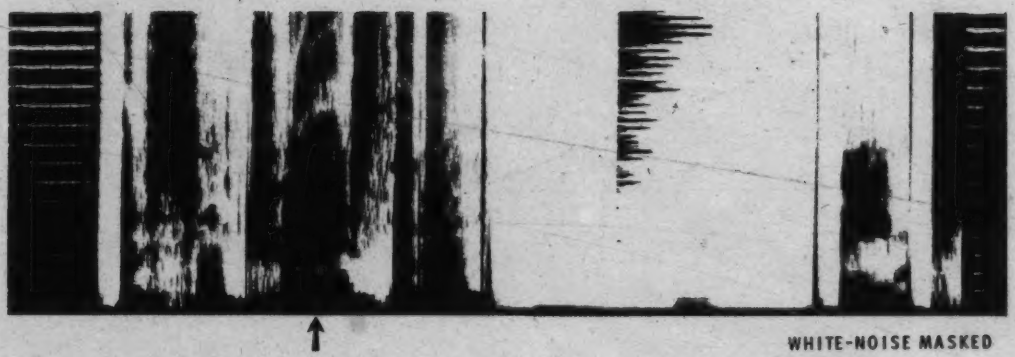

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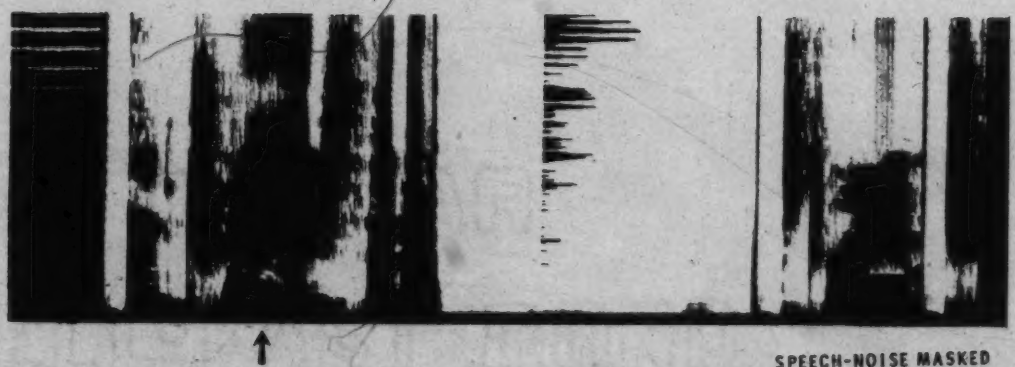


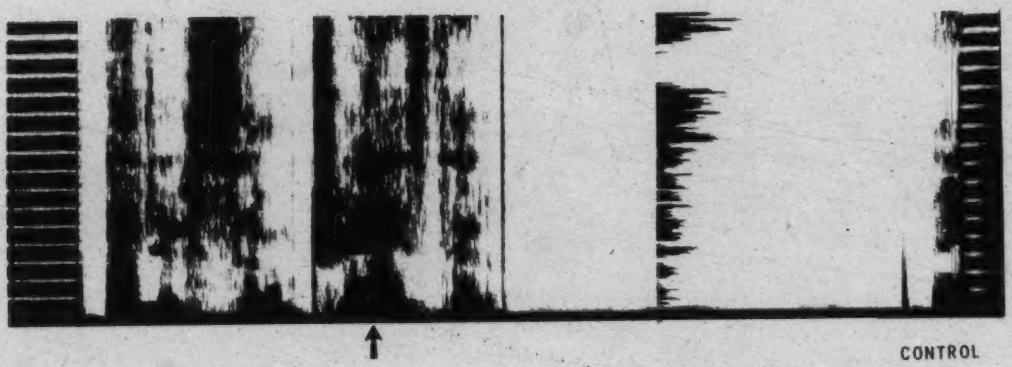
SPEECH-NOISE MASKED

FIGURE 7

Sound spectrographs of the word "trees", part of the phrase "some trees that overhung a cool stream". A section of the frequency spectrum of the vowel sound /i/ in "trees" is seen to the right of each display, and the point at which the section is taken is indicated by an arrow.

Subject: K.H.

Masking conditions as indicated.



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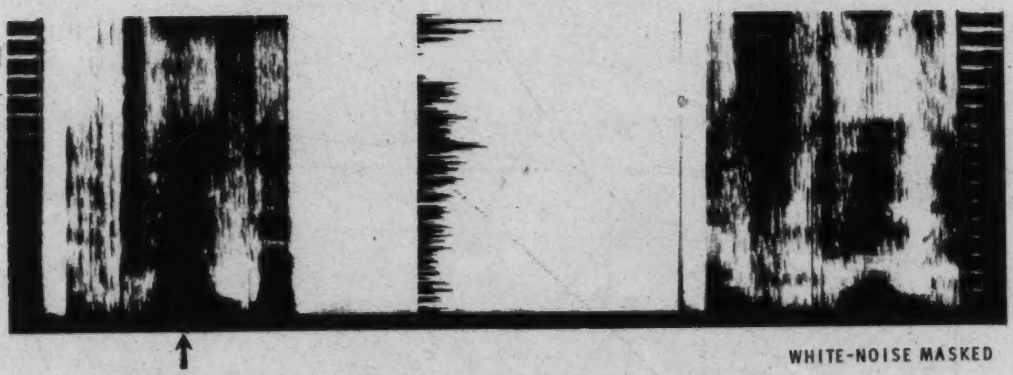

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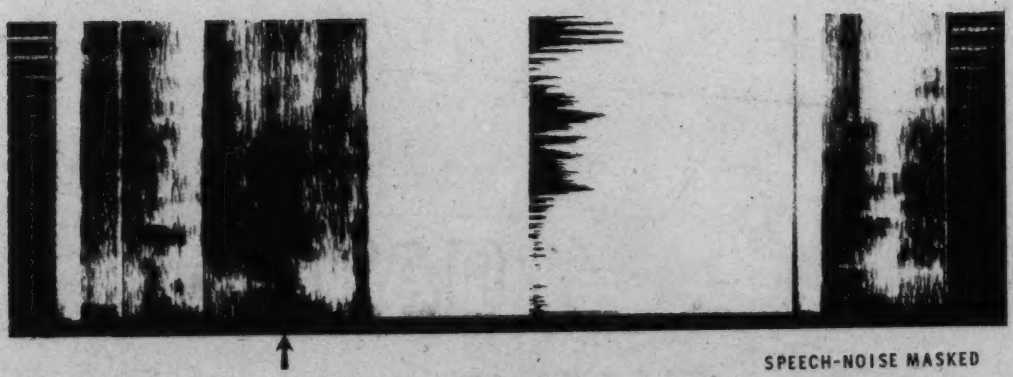


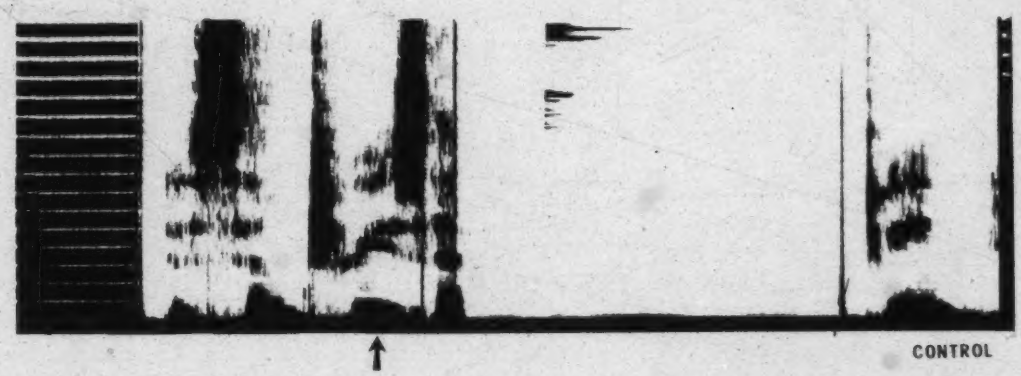
SPEECH-NOISE MASKED

FIGURE 8

Sound spectrographs of the word "trees", part of the phrase "some trees that overhung a cool stream". A section of the frequency spectrum of the vowel sound /i/ in "trees" is seen to the right of each display, and the point at which the section is taken is indicated by an arrow.

Subject: E.K.

Masking conditions as indicated.



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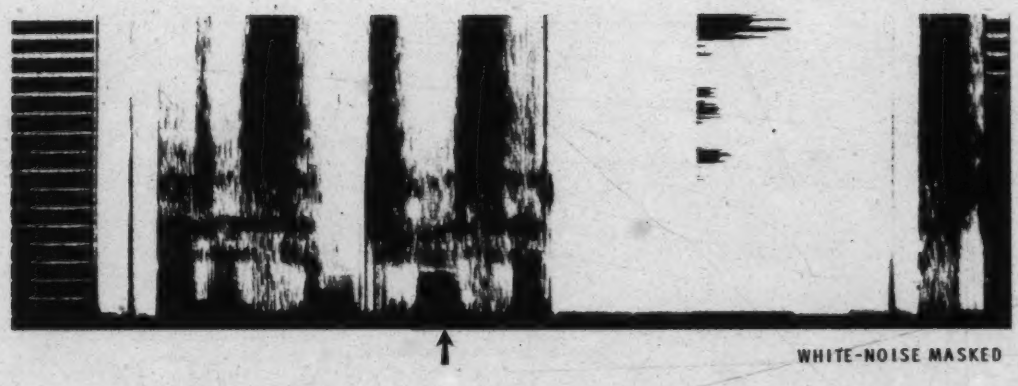

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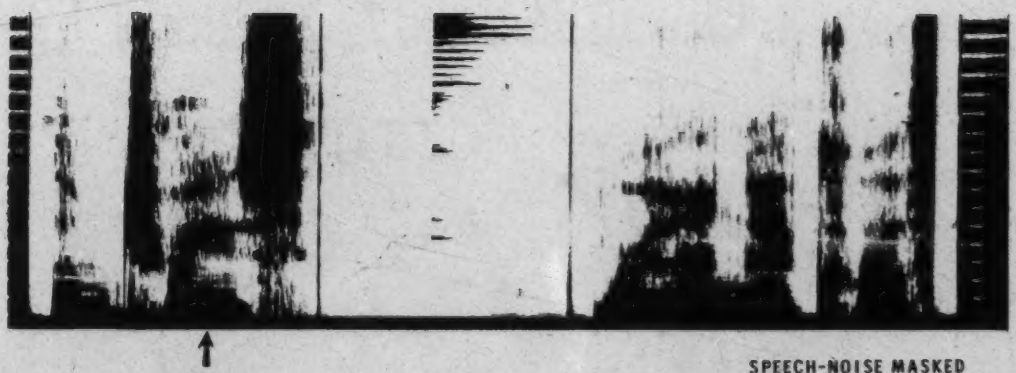


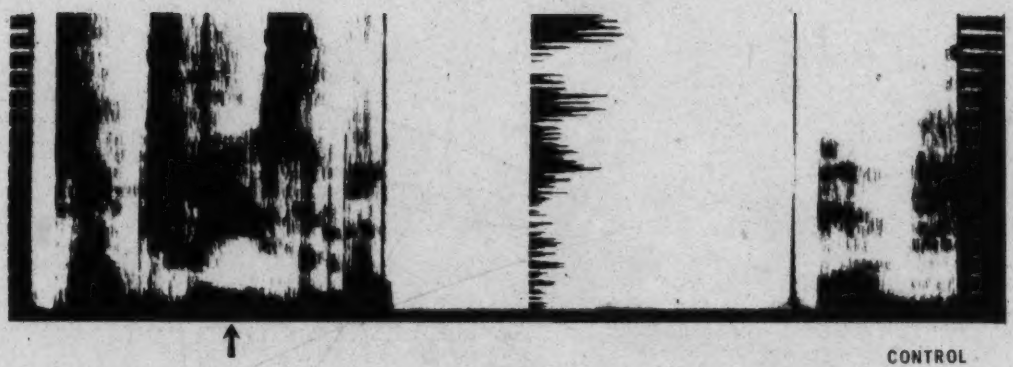
SPEECH-NOISE MASKED

FIGURE 9

Sound spectrographs of the word "trees", part of the phrase "some trees that overhung a cool stream". A section of the frequency spectrum of the vowel sound /i/ in "trees" is seen to the right of each display, and the point at which the section is taken is indicated by an arrow.

Subject: B.M.

Masking conditions as indicated.



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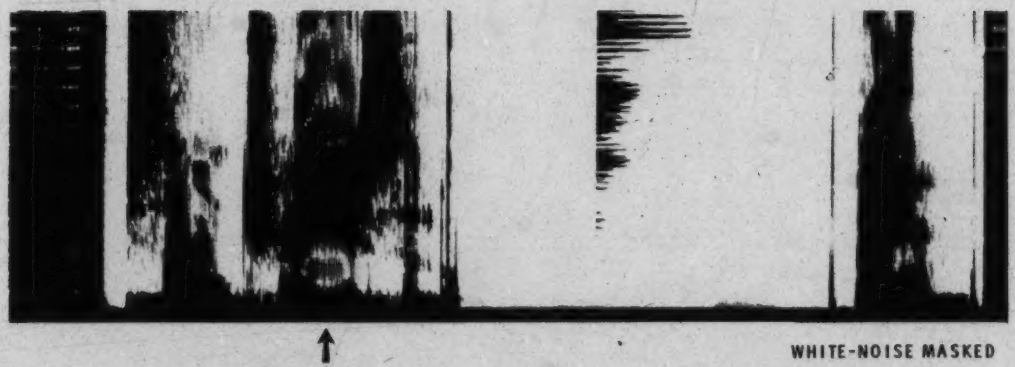

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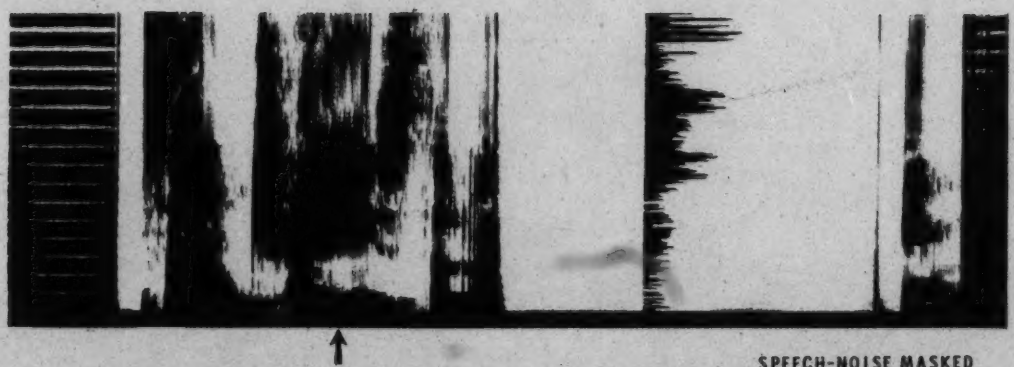


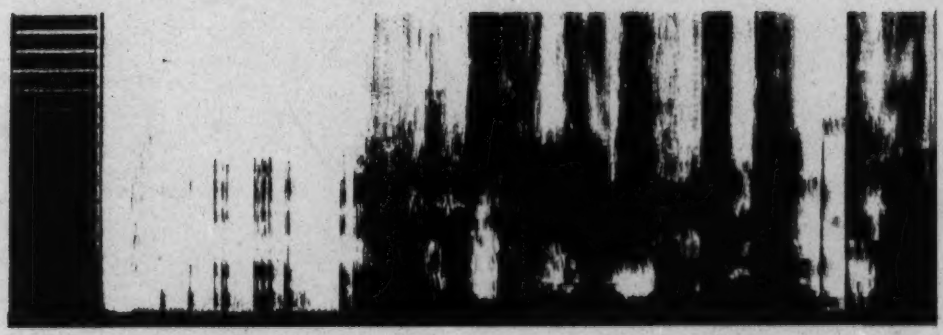
SPEECH-NOISE MASKED

FIGURE 10

Sound spectrographs of the phrase "Otters are usually nocturnal and elusive" illustrating a prolonged vocal fry onset to the first vowel in the word "otters". The upper spectrograph is of the control condition and the lower spectrograph is of the autogenic noise masked condition.

Subject: B.M.

CONTROL



SPEECH-NOISE MASKED

FIGURE 11

Sound spectrographs to illustrate vocal fry episodes occurring in the autogenic noise masked condition. The upper spectrograph displays the phrase "Canada, our true and native land" under the control condition. For comparison, the centre spectrograph displays the same phrase under the masked condition, and illustrates the vocal fry on the word "land". The lower spectrograph displays the phrase "British Columbia is on..." illustrating a prolonged vocal fry on the word "on".

Subject: B.M. Upper and centre spectrographs.

Subject: P.K. Lower spectrograph.

CONTROL

SPEECH-NOISE MASKED

SPEECH-NOISE MASKED

FIGURE 12

Oscillographic recordings which illustrate the increased intensity in the mid to high frequency range. Three separate recordings are, from top to bottom, control, white-noise masked, autogenic noise masked, respectively. The upper tracing for each recording shows the fundamental frequency; the centre tracing shows intensity above 3900 Hz. after high pass filtering; the lower tracing shows the total intensity.

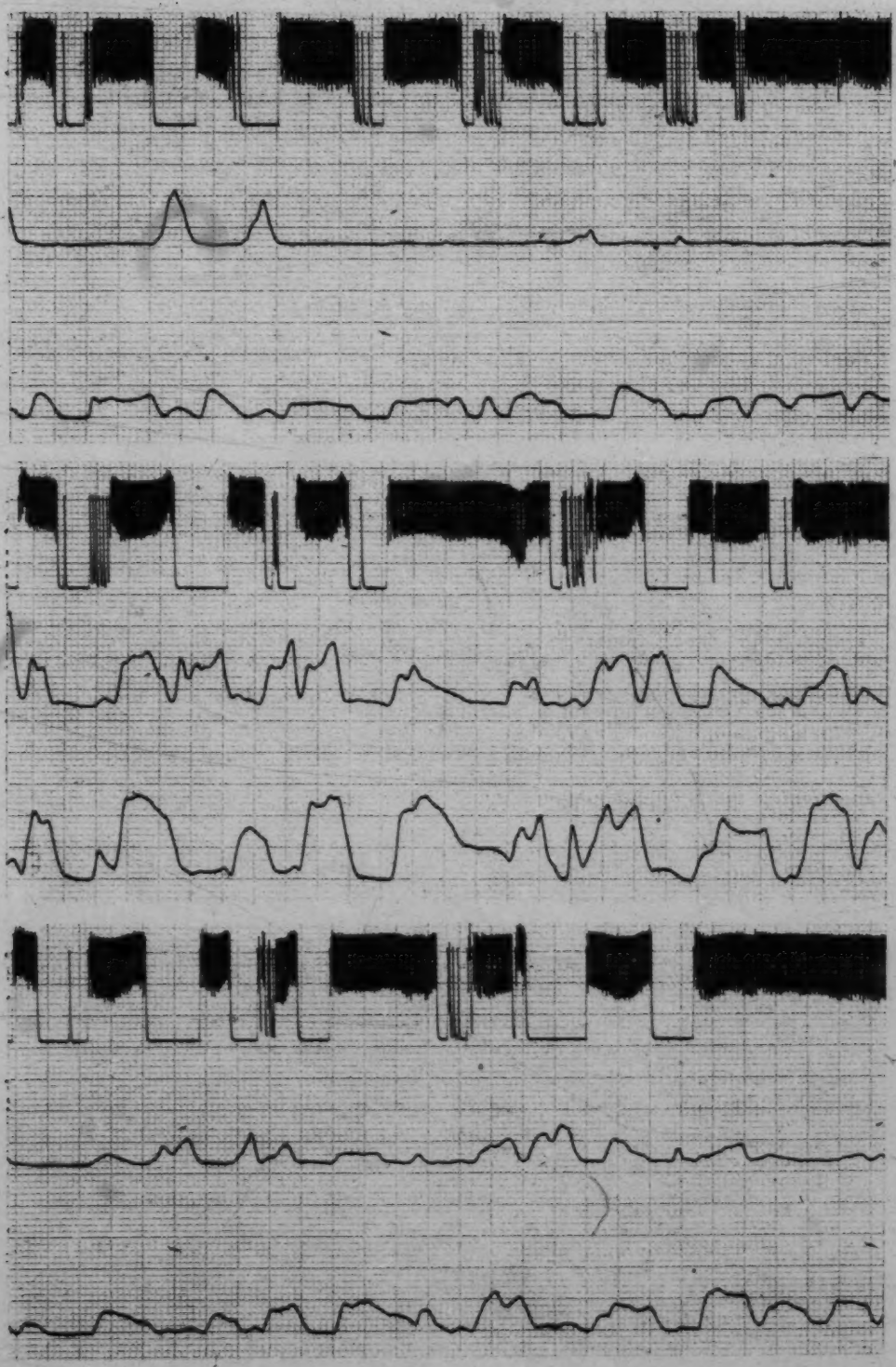
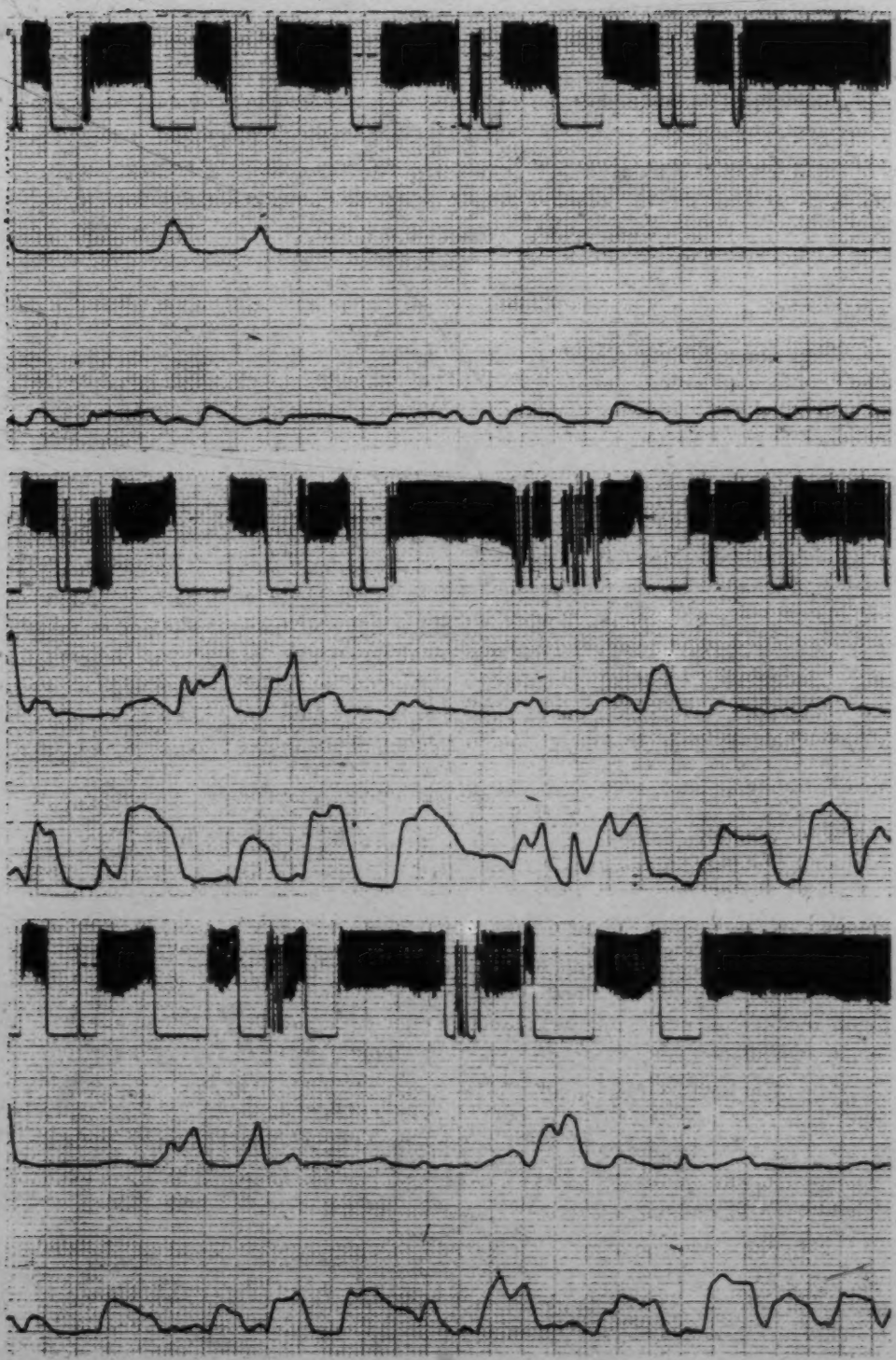


FIGURE 13

Oscillographic recordings which illustrate the increased intensity in the mid to high frequency range. Three separate recordings are, from top to bottom, control, white-noise masked, autogenic noise masked, respectively. The upper tracing for each recording shows the fundamental frequency; the centre tracing shows intensity above 5600 Hz. after high pass filtering; the lower tracing shows the total intensity.



CHAPTER FOUR

Experimental Results

1. Qualitative impressions

Initial assessment of the data tapes by listening revealed signs of disturbance in the speech output in all of the masking conditions as compared with the control. Generally, these were similar to those alterations of voice characteristics and of speech articulation noted by other authors and discussed in Chapter One. Specifically, numerous misarticulations and omissions of consonants were noted, together with both increases and decreases in rate and in intensity, the changes in rate leaving an impression of abnormal rhythmic properties. There was also a noticeable flaccidity, or laxness, of articulation particularly involving lip movements. This gave a general slurred character to the speech and lack of precision in articulation.

However, the major impression, gained from listening to the data tapes and through observing the subjects under the masking conditions, was the generalized laryngo-pharyngeal tension and strained voice quality referred to earlier. Apparently associated with this phenomenon, and occurring notably in the autogenic masking condition, were episodes of marked vocal fry: a phenomenon characterized by regular opening and closing of the opposed vocal cords, in contrast to the normal complex vibratory mode. The laryngo-pharyngeal tension appeared to persist during the masking conditions. The only exception was one teenage subject whose voice

production perhaps reflected her indifferent attitude to the experimental procedure. In this one case the tension was less marked.

2. Spectrographic data

A twelve-second segment of the standard reading passage was chosen at random. Sound spectrographic analysis of this segment was made for each subject, and condition. In the masking conditions these showed the presence of additional high frequency formants above the expected formant configurations for the particular vowel. The episodes of vocal fry can also be readily observed in the spectrographic examples. Neither of these effects were found in the control condition. Examples of both may be seen in Figure 1.

The following description of the spectrograph recordings is inserted at this point as a guide in interpreting the results shown in Figures 1 to 11. The 'complete display' sound spectrograph is illustrated in the spectrographs in Figure 1. The spectrograph displays intensity and frequency as a function of time. The horizontal axis is time, and the vertical axis frequency in the range 80-8000 Hz. with the scale defined by the striated bands on the left and right margins. Each segment of the scale calibration bands represents 500 Hz. Intensity at a given frequency and point in time is represented by the density of the tracing. When a frequency spectrum is analyzed (referred to as a 'Section') as in Figures 2-9., it is displayed

on a blanked portion of the spectrograph. The frequency spectrum shows amplitude against frequency at a particular point in time. This time point is indicated by a small arrow in Figures 2-9. The amplitude is represented by the rightward magnitude of the tracing, and the frequency scale is the same as for the complete display spectrographs, but inverted, the low frequencies appearing at the top of the spectrograph and the high frequencies at the bottom.

Sound spectrographs were made of the chosen phrase spoken under the three conditions of control, white noise masking and autogenic noise masking by each of the eight subjects was analyzed. After obtaining the sound spectrograph of the whole phrase, a second procedure was carried out using the section analyzer of the Sona-Graph yielding the frequency spectrum at a particular point in the recorded phrase. This was a section of the vowel /i/ in the word /trees/, part of the phrase /Some trees that overhung a cool stream/. The vowel /i/ contains a higher proportion of high frequency energy than other vowels; thus /i/ was felt to constitute a strong test for the presence of atypical high frequency components. As indicated earlier, the data recordings of the conditions involving the use of the laryngeal vibrator, the B conditions, contained noise that originated from the vibrator output, and were not suitable for such analysis. Interesting data were obtained from the use of the laryngeal vibrator however, and will be discussed at a later point. The sound spectrographs are displayed in Figures 2-9. Each figure presents three spectrographs of the same phrase, plus a section of the vowel

/i/, produced under each of the three experimental conditions. One figure contains the spectrographs for one subject alone. There is a consistent pattern in all subjects. In the control condition the frequency spectrum shows characteristic peaks, usually three, corresponding to the /i/ formants. There is also a low intensity band in the mid-range 2.5 k Hz - 3.5 k Hz), decreasing to very low intensity in the high frequencies. In the autogenic masking condition, the normal /i/ formants are not altered but there is evidence of additional activity in the mid to high frequency range (approximately 2.5 k Hz - 5.5 k Hz). In six subjects this extra high frequency output is relatively intense and contains discrete frequency peaks. In the complete display these appear as high frequency formants which are atypical of the vowel /i/. Also in six cases there is a weaker set of intensity peaks at very high frequencies, (6.5 k Hz. - 8.0 k Hz.). In the white noise masking condition the amount of extra activity seen in the spectrograph is intermediate between the control and autogenic noise masking conditions. The appearance of the high frequency formants is not accompanied by in the amplitude of normal spectral components under either of the masking conditions. This may be observed in the sections which show that the spectra of the normal formant grouping for the /i/ vowel remain unaltered under the masking conditions; i.e. the /i/ formants are of more or less the same intensity as in the control condition.

Figures 2-5 very clearly show the effects described above and are similar for each of those four subjects. The

differences between the masking conditions and control condition are less dramatic in Figure 6, (Subject C.N.). The pattern however, is similar to that seen in Figures 2-5 with increased activity in the middle frequency range. In Figure 7, the control and the white noise masked /i/ spectra demonstrate considerable non-specific high frequency activity. This appears to be a reflection of this subject's light, breathy, voice prodution. The voice output under autogenic noise masking does, however, show the organized broad double peak of activity, comparable to Figures 2-5.

Subject E.K. (Figure 8) was mentioned previously as apparently somewhat indifferent to the experimental procedure. Her speech became progressively more weakly voiced. The spectrographs are not really open to interpretation except that the white-noise masked condition does weakly illustrate the mid-frequency double peak, but they also show the weak voicing. The data tape of the last subject, B.M. (Figure 9) was found to contain extraneous noise with a wide frequency band, (probably ventilating fan noise). This was especially marked on the control condition section, and may be seen in Figure 9. In spite of this, the speech-noise masked condition does show the characteristic pattern seen in Figures 2-7. The two masked conditions show a very marked glottal pulse banding in the vowel /i/. This is not present at all in the control condition.

Figure 10 illustrates a prolonged vocal fry under autogenic noise masking together with the control condition

for comparison. Figure 11 shows a further episode of vocal fry on the word /land/ under the autogenic noise masking condition, together with the control condition for the same phrase. Both this phrase, and the third example in Figure 11 of a prolonged vocal fry on the word /on/, are of propositional speech, rather than prose reading.

3. Oscillographic data

Two oscillographic recordings are included because they demonstrate the increased intensity in the mid-frequency range. Changes in overall rate between the conditions are also evident in the varying length of the segments of voicing seen on the uppermost tracing (Figures 12 and 13). The changes in mid-frequency intensity are observable in the recordings of Subject N.N. but were not uniformly seen in all the oscillographic as opposed to the spectrographic recordings. It is much easier to separate out the voiceless high frequency components (e.g. fricative consonants) from the voiced components (e.g. vowels) in the spectrographs.

Figures 12 and 13 are recordings of Subject N.N. Figure 12 shows fundamental frequency on the upper tracing, total intensity on the lowest, and intensity above 3.9 k Hz. on the centre tracing. Figure 13 is a similar recording of the same phrase with the central tracing displaying intensity above 5.6 k Hz.

4. Introspective reports

Auditory masking techniques and the effects they cause are not well defined by current analytic techniques, and the objective results of this preliminary study bear only on a particular phenomenon, the tension effect. Accordingly, it was considered important to include introspective data reported by the subjects for the light they might shed on future experimental directions. Auditing the data tapes leaves certain impressions which have not been quantified.

In the immediately post experimental interviews, all subjects reported total loss of auditory feedback under the autogenic masking, and all reported some auditory feedback under white noise masking. They all also expressed a strong preference for the autogenic noise over the white noise. The white noise was actively disliked by all subjects, although no one complained that it was distressing in terms of causing physical discomfort. Questioned about the laryngeal vibrator, three of the teenage group, the four adults, and the two pilot study adults, stated that the sensation was not uncomfortable, and that they did not experience any greater difficulty in producing speech as a result of external pressure in the laryngeal area. Several subjects, one from the teenage group and two of the adults, commented that in the white noise condition, they were unaware that the vibrator was working. With the autogenic noise plus vibrator condition all the adults, including the two pilot

study subjects, and three of the teenage group felt they were less able to monitor their own speech output. They commented that they felt confused and uncertain whether they were articulating correctly although they could still speak.

These remarks made by the subjects were consonant with an evaluation of the data tapes. The use of laryngeal vibrator with the white noise masking signal did not appear to change the effect associated with the use of the air-conducted white noise signal alone. In contrast, laryngeal vibration with the autogenic masking signal produced greater effects of increased vocal tension and disrupted rhythm of speech than either of the two white noise masking conditions or the autogenic noise masking without the vibrator. The subjects' impressions that the autogenic noise signal was more effective in masking the auditory feedback of their own speech was also the impression gained by listening to the speech output on the data tapes. There were marked variations in rate, generally decreased under the autogenic noise condition and increased under the white noise, compared to the control condition. Vowel sounds appeared to be lengthened and speech had a more effortful, and yet more slurred, quality under the autogenic masking condition.

It was noticeable that among the three adults and two pilot study adults who tended to raise the amplitude of their voice under masking, none were aware of this. Three stated positively that they maintained a normal vocal loudness level. Thus it seems that the subjects' changes in voice

amplitude were unintentional. None of the teenage group raised their voices significantly and it was this characteristic that distinguished the two groups most clearly.

Three teenagers and two adults commented that the section containing the picutre description task was by far the easiest for them to perform under the masking conditions. The reason given was that they knew what they wanted to say. This was an interesting comment, because, on auditing the tapes, there seemed to be an increased tendency to hesitate, and an increase in voice tension during these sections. On the other hand, there is less rhythmic disruption in the propositional speech, and it is possible that the constraints upon rhythm inherent in a passage read aloud made the latter task more difficult under masking conditions. Two subjects specifically referred to their difficulty with "breathing at the right times", especially when reading.

5. Subject variability

Auditing of the data tapes gave a strong subjective impression that each subject showed a consistency of type of speech error in spite of the fact that the group as a whole was highly variable. For instance, one subject might show many articulation errors under the masking conditions, whereas another would show very few, or even none at all. This inter subject variability in these unmeasured responses, such as speech rate, misarticulations, and amplitude constitutes a major problem in experiments of this kind. While reports in the literature

show highly variable responses, this inter subject origin of the variance in measures of speech rate and the like, has not been emphasized.

7. Summary of results

In summary, the following physical and introspective observations have been made during the course of this experiment.

First, we were able to replicate positive effects which have been reported in previous studies on AF inhibition. Using the masking agents at a moderate intensity level, disruptions of, for example, speech rate, duration, speech articulation, and amplitude of the kind reported by earlier investigators were noted in our data tapes.

Secondly, by using a different type of masking agent, i.e. the autogenic noise which matches the spectral character of the AF, total AF inhibition was reported by subjects. The increased physical effects upon speech output under autogenic noise masking compared to white noise clearly indicates that the autogenic masking was more effective than white noise as a masking agent.

Consideration of the exploratory studies involving the laryngeal vibrator reveals indirect evidence of sensory input from the laryngeal region interacting with air-conducted autogenic masking noise to increase disturbance in speech output. This evidence was gained from auditing the data tapes and from the introspective reports of the subjects.

The major effect reported in this study is the presence of additional mid to high frequency formants in vowels produced under AF inhibition. There is significant indication that this increased and organized acoustic acoustic energy is present without change in amplitude of the normal spectral components. The phenomenon is illustrated most clearly in the spectrograph displays of all the eight subjects and, to some extent, in the oscillographic recordings.

Apparently related to the above phenomenon was a generalized laryngo-pharyngeal tension under AF inhibition. The increased occurrences of vocal fry, under autogenic noise masking in particular, provide some physical evidence of this tension, and some spectrographic illustrations have been included.

Finally, there were also certain differences in response among the subjects, which were mainly individual differences manifested in the number of articulatory errors, and alterations in speech rate, for example. These disruptions were largely independent of the age group of the subjects. One effect which appeared to be age dependent was the tendency for the adults to increase the overall amplitude of their voice under AF inhibition. The teenage group did not demonstrate this tendency, and teenage subjects tended to decrease amplitude under AF inhibition.

CHAPTER FIVE

Discussions and Conclusions

(i) Experimental Validity

Questions concerning the relevance of an experimental procedure with respect to the phenomena ostensibly under investigation are particularly important in such cases as the present one. It is doubtful whether our masking treatments have any real parallel in natural phenomena. Ambient noise is not likely to provide the degree of masking over air and bone conducted AF that we obtain under these experimental conditions. However, the primary evidence in nature for the contribution of AF to motor control in speech is in speech changes following anacusis with sudden onset in the adult or the linguistically viable child. Accordingly, it seems appropriate to consider the relevance of the experiments reported here to those changes in motor performance which characteristically occur in nature with the sudden onset of anacusis.

In anacusis, the observed patterns of voice and articulatory change clearly result from sensory loss while our experimental conditions involve the introduction of sensory noise. The critical point, however, is that in both cases a specific sensory input is lost to the speaker: the acoustic feedback of the speech signal. It is on the basis of this point that the relevance of the experimental treatment to presumed effects of sensory inhibition must rest. This is not to assume the absence of response artifacts due to the experimental treatment; attempts to isolate such effects are discussed below.

A second, and important, difference between speech effects associated with anacusis and those found in our experiments lies in the matter of temporal onset. In anacusis speech change is slow in onset, taking several months to develop, while in the masking experiments the onset is immediate. At face value, this might suggest a basis for invalidating the masking experiments with respect to their relevance for the natural phenomena associated with sensory inhibition. Such a view might, however, obscure the actual complexity of the natural phenomena through a misplaced emphasis on questions of experimental validity. Instead, we might ask what kind of mechanism could, after sudden deafness, support normal speech for a period of several months but be unable to continue this support indefinitely, and what is there about the experimental condition which might inhibit the activity of such mechanisms.

More generally, in order to examine the validity of our experiments in relation to phenomena of AF inhibition and to the fundamental problem raised by the occurrence of AF, it will be necessary to evaluate a number of hypotheses that might provide alternative explanations for the reported effects. Throughout the following discussion, it will be important to bear in mind a point made in Chapter Two; this is the possibility that an AF loop might be closed at one or more of the different neurological levels involved in speech production. The occurrence of AF presumably enables the speaker to monitor his speech output along many dimensions. In this study interest is focused not on

psycholinguistic monitoring, but on physiological sensory feedback in relation to presumed direct mechanisms of motor control.

(ii) Frequency Component Effects

A notable feature of the experimental results is the appearance of shaped energy at the 2.5 k Hz. to 5.5 k Hz. range. Under white noise masking the prominence of this feature lies between that found under autogenic masking, where it is most prominent, and that found under the control condition, where the experimental effect is absent.

These findings are different from earlier reports, which describe disturbances in articulation, fundamental frequency, speech rate, rhythm, and overall intensity. The effects we have seen in the form of additional mid to high frequency formants in vowels would seem to be evidence of induced changes of the vocal production mechanism. Such effects could presumably only originate in differences in the behaviour of the laryngeal musculature. The normal vowel formants, as seen in the sound spectrographs of the control condition, are produced by the configurations of the vocal tract acting upon the harmonics of the glottal wave form. A possible origin of the extra mid to high frequency formants seen under masking is a sharpening of the saw-tooth wave form, giving rise to higher frequency components. The appearance of these 2.5 k Hz. to 5.5 k Hz. frequency components is, on the basis of the experiments reported here, a constant effect across subjects, though

its prominence appears to depend on individual subject characteristics. The prominence effect associated with different masking conditions, being greater under autogenic than white noise at 85 dB above threshold, appears to be constant across subjects.

The episodes of vocal fry appear to be related to a generalized laryngo-pharyngeal tension, and could possibly be explained as intermittent muscle tension under AF inhibition in addition to the increased tension we have suggested in the laryngeal muscles.

(iii) Interpretation of the Frequency Component Effects

It might be argued that the appearance of the added frequency components is best understood as a response artefact resulting from non-specific stress introduced by the masking signals. This does not seem likely, however, in view of the following considerations. First, we should note that the prominence of the added frequency components is greater under autogenic masking then under white noise masking. Under a response artefact hypothesis, this prominence effect should mean that subjects were more stressed by autogenic than by white noise. However, introspective reports by subjects directly contradict this: subjects unanimously reported that white noise was more stressful than autogenic noise. Thus a response artefact hypothesis would introduce a paradoxical relationship between the prominence effect and the introspectively reported stress effect.

A response artefact hypothesis might, however, be

proposed to explain the immediate onset of speech disturbance under AF masking, as opposed to the slow onset observed following anacusis. If this is correct, then we should expect incremental improvement in speech production under prolonged treatment as subjects accommodate to the experimental stimulus. As noted in Chapter Three, we have not tested an accommodation hypothesis, but the response artefact hypothesis is nevertheless not entirely satisfactory for the reasons already indicated.

The differential effects of white noise present puzzles in relation to the prominence effect for the added frequency components. The paradox itself might be reasonably explained on the basis of laterality of brain function; Kumura (1973) points out that speech signals and noise are processed in opposite hemispheres. We might suppose that if white noise, because of its lack of organization, is mainly processed in the non-dominant hemisphere, while autogenic noise is processed in the dominant, then autogenic noise should disturb speech functions more severely than white noise. Under a lateralization hypothesis, we might assume that the presence of white noise in the non-dominant hemisphere introduces a psychologically disturbing condition because it involves interhemisphereic stimulus competition. If we assume lateralization to be operative, along the lines indicated above, and also take into consideration the reported introspective accounts on the relative weakness of white noise as an AF masking agent, then we might account for both the

treatment response paradox and the added frequency prominence effect, subjective disturbance under white noise being due to relatively weak AF inhibition.

(iv) Differential Control Loops

If we compare the added frequency effect with induced speech disturbances of the more familiar kind associated with AF inhibition studies, there appear to be two distinctly different types of effect when AF is inhibited. One is the previously reported intermittent disruption of articulatory segments, and the other is the alteration in voice characteristics. The latter would presumably arise from changes in activity of the laryngeal muscles, as already noted. The fact that interference with AF causes alterations in speech output implies that such feedback is an element in the control of speech production. But the two kinds of disturbance in speech output suggest that two different feedback pathways may be implicated under AF masking.

Interference with highly organized levels of speech required for segment articulation yields intermittent effects of the misarticulation type noted by all investigators. This suggests either an unregulated open loop, IIA, or else a closed loop, IIb, with a relatively low functional load, operating at a relatively high brain level. By "unregulated open loop" we mean to suggest a central motor program with some vulnerability to disturbance in the presence of extraneous signals.

The highly stable voicing effects observed in our

experiments, perhaps associated with previously reported changes in fundamental frequency, suggest a different loop, I. The characteristic stability of presumed loop I effects observed in our experiments suggest that this is a closed loop. Such a loop would presumably have its effect at lower brain centres than would loop II, and be involved in the control of voice production.

Our results are thus consonant with the familiar distinction between speech and voice. However, the distinction between articulatory segment and voice character effects raises difficulties when we attempt to assess the role of AF in speech control. These difficulties are addressed in the following sections.

(v) Laryngeal Proprioception

The joints and intrinsic muscles of the larynx are known to be supplied with proprioceptive end organs (Wyke, 1969). We have observed indications of sustained tension in the laryngeal region under AF inhibition, and the added frequency components seen in the spectrographic data are presumed to be direct results of increased muscular tension in the larynx. These effects might be interpreted as evidence of an extra loading on the laryngeal proprioceptive system which might result in an afferent compensation for lost AF.

A compensatory mechanism with this function would, under a closed loop hypothesis, explain why speech following anacusis retains efficient motor control. Indeed, speech therapists give particular emphasis to kinesthesia in speech

production in the deaf. Unfortunately, we do not have a spectrographic data on post-anacusis speech; it would be interesting to see whether or not the added frequency components observed under AF masking appear in this form of speech. The point is worth considering since the possibility is that the added frequency components seen in our experiments may evince an attempt to shift information-bearing components of the spectrum above the otherwise effective autogenic masking noise.

The interpretation that we have placed on our data concerning laryngeal tension, including the appearance of new frequency components, would require us to view loop I as capable of being closed by either acoustic or proprioceptive afferents.

(vi) Integrated Control Mechanisms

The possibility of alternative closing for loop I suggests that the significance of AF might not be readily appreciated if we view it in isolation. The suggestion that proprioceptive activity may increase in partial compensation for lost AF would tend to emphasize the significance of loop closure rather than the sensory modality in the loop. After laryngectomy AF is normally available, while post-anacusis speech has recourse to kinesthesia from proprioception. Thus a direct testing for a closed loop of the kind we have postulated, and an assessment of its functional significance, would require deprivation of laryngeal proprioception in combination with AF masking. In this respect,

it would be interesting to observe laryngectomees under AF masking.

In our experiments binaural AF masking with autogenic noise combined with laryngeal vibration produced the most severe disruptions of speech. With the exception of one teenage subject whose general unresponsiveness was noted in Chapter Four, all subjects under this experimental condition, including the two adults who served in the pilot studies, appear to have experienced a sense of diminished motor control and a marked tendency to thought blockage. It would be interesting to determine by further experiments whether prolonged experimental treatment would tend to show further decrement or an improvement due to accommodation. Meanwhile, the evidence that we have from the present experiments has some value. If we accept the hypothesis that increased proprioceptive feedback acts in response to AF loss, then our experimental condition II(b) would create a severe afferent inhibition. The fact that this experimental condition produced the greatest disturbance in speech production is, at any rate, in conformity with the alternative closure hypothesis. Under this hypothesis, the fact that speech shows deterioration after anacusis and under AF masking would suggest that proprioception acts less efficiently than AF.

(vii) Immediate Onset Effects

The above discussion of possible compensatory response to AF loss does not account for an important experimental effect: the immediate onset of speech disturbance under AF

masking as opposed to its slow onset following anacusis.

In our experiments, including the pilot studies, most subjects volunteered an introspective report of a kind which seemed insufficiently precise to warrant inclusion in Chapter Four. The tenor of these reports suggests the possibility that a speaker has recourse to an awareness of his speech other than from direct AF or proprioceptive feedback, and that the immediate basis for this awareness is an endogenic acoustic image or acusma for the sound of his voice. Reports along these lines were most commonly made in relation to experimental condition II(b), though they were also made under condition II(a): binaural autogenic masking.

If we assume that in addition to increased proprioceptive feedback, the post-anacusis speaker has recourse to such acusmata, we might be able to explain the preservation of normal speech for several months after the onset of anacusis. This would imply that feedback may be provided by the acusmata independently of the exogenic AF. The later collapse of fine control in speech would have to be explained by assuming the maintenance of acusmata is dependent on reinforcement by the exogenic wave-form.

In section (iii) of the present chapter, we argued that a response artefact hypothesis would not account for speech disturbances observed under AF Masking. This argument referred to the possibility that the observed speech disturbances are not due to sensory inhibition in a closed loop

system but to a non-specific disturbance caused by a strong sensory input. We wish to let this argument stand, but we do wish to introduce a closely related hypothesis. If the acusmata that we have entertained thus far occur at all, then they must arise from neuronal activity in the cerebral auditory nuclie. If, under our AF masking conditions, the masking noise triggers neural responses which drown the activity of nuclei responsible for the acusmata, then the latter would not be available as a source for endogenic AF. This would explain the immediate onset of speech disturbance under our AF masking.

(viii) Future experiments

It is unfortunate that the limitations of the experimental equipment prevented instrumental analysis of the output data from the vibrator experiments. However, the effect is clearly important, if not well defined, in the present experiments. In future, experiments might be devised using better techniques and equipment so as to prevent the sound, radiating from the vibrator, appearing on the data tapes.

One implication of the results reported is that future experiments in this field will probably involve the study of consistent underlying effects rather than the more obvious but variable effects studied in the past. This implies the detailed studies of speech output of relatively small numbers of subjects. The alternate approach involves phenomenological study which concentrates on analyzing highly

variable disruptions of speech in large numbers of subjects. On the basis of previous results, this approach will not yield information leading to understanding of the basic mechanisms. Ringel, one of the leading workers in this field, has published a study which appeared during the preparation of this thesis (Horii et al, 1973) which indicates a similar approach.

(ix) Summary

1. Autogenic noise at 85 dB above threshold appears to provide an effective masking for air and bone conducted AF.
2. Added frequency components observed under AF masking appear to be best explained in associated with an increased muscular tension in the larynx. This tension is interpreted as evidence of increased laryngeal proprioceptive traffic in compensation for AF loss.
3. The added frequency components, when considered together with changes in articulation, suggest two distinct types of change under AF. One change affects highly organized aspects of speech associated with a relatively high level of brain activity; the other change affects voice quality, which would appear to be mediated by lower brain centres.
4. The intermittent effect of AF masking on articulation segments suggest that articulation control is provided by an somewhat unstable open loop or a closed loop of relatively low functional load. The stable effect of AF masking on voice quality suggests a closed loop control.

5. AF and proprioceptive feedback appear to be represented in the voice control loop, with proprioceptive increase in partial compensation for AF loss, though AF is more important for laryngeal motor control than is proprioceptive feedback.
6. Two distinct stages of speech after sudden anacusis appear to be explicable in relation to effects observed in the AF masking experiments. An hypothesized endogenic AF dependent on reinforcement from exogenic AF may support normal speech immediately after sudden anacusis, but amnesia for this feedback source will appear beyond the reinforcement period, thus giving rise to speech disturbances comparable to those seen in AF masking. In the experimental situation, the neural source of endogenic AF is presumed to be drowned by neural response to the exogenic masking signal, thus providing a basis for immediate onset of speech disturbance.
7. The superiority of autogenic masking over white noise masking is most readily explained by the fact that autogenic noise is spectrally shaped to fit the AF. Possibilities of lateralization effects for the two masking agents are considered to account for the differential effect of white noise for subject discomfort and AF masking.
8. Evidence of AF contribution to motor control in speech suggests that more than one loop may be implicated. Until more detailed investigations have been made, the

significance and mode of integration between such loops prevents a clear assessment of the significance of AF.

9. Recommendations are made for further studies on various aspects brought to light in the present research. One important problem for further study concerns possible sources for subject x treatment interactions.

APPENDIX A

The following material was presented to the subjects in the same order for each condition. For conditions in which the laryngeal vibrator was used, only the passage of prose was presented. Each section was preceded by the instruction written on a separate page.

Page 1. Please follow the instructions which will be presented here. Try to speak in your usual way without shouting.

1. Please answer the following questions aloud, making a sentence for each.

Page 2. What is your name?

Who is the mayor of the City of Edmonton?

From what vegetable would you make a Halloween Jack O'Lantern?

What are the names of three of Canada's largest cities?

What is the name of the river on which Edmonton is situated?

Can you say the first line of the National Anthem?

What province is west of Alberta, and on what ocean is it's coast?

Page 3. Please read the following passage aloud in your usual manner.

Page 4. Otters are usually nocturnal and elusive. Some years have passed since I found a place near tidal

waters where, at dusk at this time of year, I was able to watch an otter family at play on successive occasions. The present summer weather has provided me with a daytime sighting of an otter. I had reached the shade of some trees that overhung a cool stream and it was while enjoying a state of heat-induced inactivity there that I became aware of the movement of an animal with a large tail, on the opposite bank. At this point the stream consisted of shallows separated by deeper pools. The trees grew from a hedge which formed the opposite bank of the stream; one of these trees had fallen. The movement that I had seen was beside the upturned roots of this tree. Soon the otter came through an opening and scurried along the waterside. Then with quick movements it returned to the hole among the roots, only to re-emerge later with a trout in its jaws.

Page 5. Please look at the following pictures. Describe what you see - talk about them in any way you wish.

Page 6-9 Pictures mounted on paper, which contained enough activity or scenery to make description as straightforward as possible.

REFERENCES

Bekesy, G. von — The structure of the middle ear and the hearing of one's own voice by bone conduction. Journal of the Acoustical Society of America, 1942, 21, 217-232.

Bekesy, G. von & Rosenblith, W.A. — The mechanical properties of the ear. In: Handbook of Experimental Psychology, S.S. Stevens (ed.), Wiley, New York, 1951.

Black, J.W. — The effect of sidetone delay upon vocal rate and intensity. Journal of Speech and Hearing Disorders, 1951, 16, 56-60.

Bredberg, G.; Lindeman, H.H.; Ades, H.W. & West, R. — Scanning electron microscopy of the organ of Corti. Science. 1970, 170, 3960, 861-863.

Burke, B.D. — Reduced auditory feedback and stuttering. Behavior Research and Therapy, 1969, 7, 303-308.

Cherry, C. & Sayers, B. McA. — Experiments upon the total inhibition of stammering by external control. Journal of Psychosomatic Research, 1956, 1, 233-246.

Eccles, J.C. Functional organization of the cerebellum in relation to it's motor control. In: Muscular Afferents and Motor Control, R. Granit (ed.), Wiley, New York, 1966.

Gammon, S.A.; Smith, P.J.; Daniloff, R.G. & Kim, C.W. Effect of level of distracting noise on speaking rate, duration and intensity. Journal of Speech and Hearing Disorders, 1949, 14, 363-368.

Horii, Y.; House, A.S.; Li, K.P. & Ringel, R.L. Acoustic characteristics of speech produced without oral sensation. Journal of Speech and Hearing Research, 1973, 16, 1, 67-77.

Kimura, D. The Asymmetry of the Human Brain. Scientific American , 1973, 228, 70-78.

Ladefoged, P. Three Areas of Experimental Phonetics, Oxford University Press, London, 1967.

Lane, H. & Tranel, B. The Lombard Sign and the role of hearing in speech. Journal of Speech and Hearing Research, 1971, 14, 4, 677-709.

Lashley, K.S. The problem of serial order in behavior. In: Cerebral Mechanisms in Behavior, L.A. Jeffress (ed.), Wiley, New York, 1951.

Lee, B.S. Effects of delayed speech feedback. Journal of the Acoustic Society of America, 1950, 22, 824-826.

_____ Artificial stutter, Journal of Speech and Hearing Disorders, 1951, 16, 63-65.

Lombard, E. La signe de l'elevation de la voix. Annales des Maladies de l'Oreille, du Larynx, du Nez et du Pharynx, 1911, 37, 101-119.

MacCulloch, M.J.; Eaton, R. & Long, E. Long term effect of auditory masking on young stutterers. British Journal of Disorders of Communication, 1970, 5, 2, 165-173.

Miller, G.A. The masking of speech. Psychological Bulletin, 1947, 44, 2, 105-129.

Ringel, R.L. & Steer, M.D. Some effects of tactile and auditory alterations on speech output. Journal of Speech and Hearing Research, 1963, 6, 369-378.

Silverman, F.H. & Goodban, M.T. The effect of auditory masking on the fluency of normal speakers. Journal of Speech and Hearing Research, 1972, 15, 543-546.

Stromsta, C. Delays associated with certain sidetone pathways. Journal of the Acoustical Society of America, 1962, 34, 4, 392-396.

_____ Interaural phase disparity of stutterers and non-stutterers. Journal of Speech and Hearing Research, 1972, 15, 771-780.

Sussman, H.M. & Smith, K.U. Jaw movements under delayed auditory feedback. Journal of the Acoustical Society of America, 1971, 50, 2 (Part 2), 685-691.

Van Riper, C. The use of delayed auditory feedback in stuttering therapy. British Journal of Disorders of Communication, 1970, 5, 1, 40-45.

Wyke, B.D. Laryngeal Reflexes in Speech. British Journal of Disorders of Communication, 1969, 4, 1, 3-25.